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THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hæreere, atque his uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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#### CORRIGENDA.

Page vi, lines 5-8 from top, insert a query after each of the species mentioned as occurring in the *Olenellus*-zone at Nuneaton.

Page 201, top line, before 'few' insert 'a.'

Page 487, 12th line from bottom, read '*Dendrophrya*' for '*Dendrophyra*.'

Page 487, 14th line from bottom, read '? *Dendrophrya*' for '*Dendrophora*.'

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THE  
QUARTERLY JOURNAL  
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THE GEOLOGICAL SOCIETY OF LONDON.  
VOL. LII.

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1. *The 'SCHISTES LUSTRÉS of MONT JOVET (SAVOY).*

By J. W. GREGORY, D.Sc., F.G.S. (Read November 6th, 1895.)

THE controversy as to the age and origin of the 'Schistes lustrés' of the Western Alps has passed through three distinct stages. At the beginning of the century these schists were included among the primitive rocks. Even in the first decade, however, this idea was refuted in a paper by Brochant,<sup>1</sup> which may still be read with interest, owing to its excellent description of the physical features of the Tarentaise. In this work, all the rocks of which Mont Jovet is composed, with the exception only of the gypsum, were referred to a series of 'terrains de transition,' intermediate between the crystalline primitive rocks and the normal, secondary, stratified deposits. Fifteen years later, a further advance was made, which restricted the 'terrains primitifs' within still narrower limits. Bakewell<sup>2</sup> then showed that the gypsums of Mont Jovet were regularly interstratified with the limestones; moreover, as he correlated the anthracitic beds with the English Coal Measures, he included the limestones in the 'upper secondary strata,' meaning thereby the Permian and the Mesozoic. A second stage in the controversy was entered upon with Elie de Beaumont's<sup>3</sup> epoch-making discovery of belemnites in the limestones of Petit-Cœur, a hamlet 5 miles north-

<sup>1</sup> A. J. M. Brochant, 'Observations géologiques sur des terrains de transition qui se rencontrent dans la Tarentaise et autres parties de la chaîne des Alpes,' Journ. des Mines, vol. xxiii. (1808) pp. 321-380.

<sup>2</sup> R. Bakewell, 'Travels ... in the Tarentaise and various parts of the Grecian and Pennine Alps in the years 1820-1822,' London, 1823, vol. i. pp. 295-300.

<sup>3</sup> Elie de Beaumont, 'Notice sur un Gisement de Végétaux fossiles et de Bélemnites, situé à Petit-Cœur près Moutiers, en Tarentaise,' Ann. Sci. Nat. vol. xiv. (1828) pp. 113-127.

west of Mont Jovet. In consequence of this, Fournet,<sup>1</sup> in his map, marked the whole of the rocks of the mountain as Jurassic; while, later on, Lory,<sup>2</sup> who knew the locality well, identified the schists and limestones of the summits as altered Trias. In spite of the protests of the Italian geologists, who referred the 'Schistes lustrés' either to the early Palæozoic<sup>3</sup> or to the Archæan crystalline series,<sup>4</sup> the weight of Lory's influence gained general acceptance for his view. It was not till 1887 and 1889 that Zaccagna<sup>5</sup> and Bonney<sup>6</sup> carried the controversy into the third phase by the independent description of some sections across the Cottian Alps, which showed a marked unconformity between the Trias and the 'schistes lustrés,' and thus proved the pre-Mesozoic age of the latter.

These two papers both described areas which Lory had previously mapped, and on which he rested his conclusions. In spite, therefore, of the clearness of the descriptions of the two authors, their conclusions have not been generally accepted. The official map of the French Geological Survey on the scale of 1:1000,000, issued in 1889, is coloured in accordance with Lory's views. Diener,<sup>7</sup> though accepting most of the 'Kalkschiefer' (or 'schistes lustrés') as pre-Mesozoic, still includes part of them in the Trias. Kilian,<sup>8</sup> in his lucid and judicious discussion of the question, holds that as the presence of these schists seems to exclude that of the Carboniferous, it is possible that they are the altered representatives of the rocks of this system. Parona's<sup>9</sup> discovery of radiolaria in the schists in the typical sections near Cesana has thrown further doubt on the Archæan age of the beds; while, still more recently, Marcel Bertrand<sup>10</sup> has gone back unreservedly to the theory of the Mesozoic age of the 'schistes lustrés.'

<sup>1</sup> J. Fournet, 'Mémoire sur la Géologie de la partie des Alpes comprise entre le Valais et l'Oisans,' Ann. Soc. roy. Agric. Lyon, ser. 2, vol. i. (1849) pp. 201-202, pl. i.

<sup>2</sup> C. Lory, 'Description géologique du Dauphiné,' Bull. Soc. Stat. Isère, ser. 2, vol. vii. (1864) p. 16; 'Carte géologique de la Maurienne et de la Tarantaise (Savoie),' Bull. Soc. géol. France, ser. 2, vol. xxiii. (1866) p. 481; 'Sur la Constitution et la Structure des Massifs de Schistes cristallins des Alpes occidentales,' Compt. Rend. Congrès Géol. Internat. sess. 4 (Londres, 1888), p. 93.

<sup>3</sup> As, *e. g.*, B. Gastaldi, 'Studii geologici sulle Alpi occidentali,' pt. i., Mem. descriz. Carta geol. Italia, vol. i. (1871) pp. 16-19.

<sup>4</sup> As, *e. g.*, M. Baretta, 'Studi geologici sulle Alpi Graie settentrionali,' Mem. R. Accad. Linc. ser. 3, vol. iii. (1879) pp. 484-486, pl. i.

<sup>5</sup> D. Zaccagna, 'Sulla Geologia delle Alpi occidentali,' Boll. R. Com. geol. Ital. vol. xviii. (1887) pp. 346-417, pls. ix.-xi.

<sup>6</sup> T. G. Bonney, 'Notes on Two Traverses of the Crystalline Rocks of the Alps,' Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 67-109.

<sup>7</sup> Diener, 'Gebirgsbau der Westalpen,' Vienna, 1891, p. 103.

<sup>8</sup> W. Kilian, 'Notes sur l'Histoire et la Structure géologique des Chaînes alpines de la Maurienne, du Briançonnais et des Régions adjacentes,' Bull. Soc. géol. France, ser. 3, vol. xix. (1891) pp. 579-580.

<sup>9</sup> C. F. Parona, 'Sugli Schisti silicei e radiolarie di Cesana presso il Moncenisio,' Atti R. Accad. Sci. Torino, vol. xxvii. (1891-92) pp. 305-319.

<sup>10</sup> Marcel Bertrand, 'Etudes dans les Alpes Françaises.—Structure en Eventail, Massifs amygdaloïdes et Métamorphisme,' Bull. Soc. géol. France, ser. 3, vol. xxii. (1894) pp. 69-118, pls. iv.-vi.; 'Schistes lustrés de la Zone centrale,' *ibid.* pp. 119-162, pl. vii.

This divergence of view is doubtless due in part to the fact that the 'schistes lustrés' cover a considerable extent of country, and the different theories rest on the interpretation of different sections. Fortunately, however, Zaccagna<sup>1</sup> and Bertrand<sup>2</sup> have both recently described Mont Jovet, and each claims that it supports the two rival theories.<sup>3</sup>

Mont Jovet has long done service in geological controversy, as it is situated close to Moutiers, where a school of mining flourished at the beginning of the century. Its structure was investigated then, and it has been repeatedly revisited. Fournet in 1849 claimed it all as altered Jurassic; while Lory, who worked over it with care, identified the rocks of the central group of peaks as part of his 'schistes lustrés calcareo-talqueux du Queyras et des vallées piémontaises,' and therefore as Triassic. Favre,<sup>4</sup> who briefly described the mountain in 1867, suggested that the limestones of this series might be Jurassic. Zaccagna, like Lory, accepted the central rocks as 'schistes lustrés,' but he gave a section across the mountain, showing a marked unconformity between these and both the Trias and the Carboniferous. He therefore regarded the mountain as 'an isolated outskirt of the Upper Archæan zone which rises through the stratified rocks between the Isère and the Doron, and which, being constituted of calc-schists, has been hitherto united to the Triassic formation. It was probably part of the eastern covering of the zone of lower crystalline schists which passes to Cévin, being united in a synclinal to the calc-schists, which ought also to cover the western side of the nucleus of the Vanoise.'<sup>5</sup>

Bertrand, on the contrary, describes the mountain as having exactly the opposite structure. According to him it is 'un noyau synclinal ouvert entre les deux branches étirées d'un même pli anticlinal' (*op. cit.* p. 100). Or, as he concludes elsewhere (p. 125), although there are some uncertainties, 'there is no doubt that it is impossible to claim that one can see there a Palæozoic island, for it is in fact a *paquet* of Lias, perhaps with Triassic schists at the base, placed on the summit of the fan.'

Practically the two observers simply invert the mountain. The central rock which forms the summit, according to Zaccagna, is an Archæan schist; according to Bertrand, it is a Liassic limestone identical, save for the absence of belemnites, with the adjoining flags with *Belemnites truncatus* (*op. cit.* p. 124). According to Zaccagna the rocks of the summit are an island, on the flanks of which the Triassic and Carboniferous beds were unconformably deposited; according to Bertrand the rocks of the summit were

<sup>1</sup> D. Zaccagna, 'Riassunto di Osservazioni geologiche fatte sul versante occidentale delle Alpi Graie,' Boll. R. Com. geol. Ital. vol. xxiii. (1892) pp. 229-231, 396-397.

<sup>2</sup> M. Bertrand, *op. cit.*

<sup>3</sup> For an abstract of these two papers, see J. W. Gregory, 'Recent Contributions to the Geology of the Western Alps,' Science Progress, vol. iii. (1895) pp. 147-174.

<sup>4</sup> A. Favre, 'Recherches géologiques dans les parties de la Savoie, du Piémont et de la Suisse voisines du Mont Blanc,' vol. iii. (1867) pp. 230-231.

<sup>5</sup> Zaccagna, *op. cit.* (1892) p. 397, & pl. v. sect. 2.

laid down later, and upon the others. In fact, what according to Zaccagna is the oldest rock in the mountain, according to Bertrand is the newest.

The differences, moreover, are as important as they are absolute. According to Bertrand, the 'schistes lustrés' pass laterally into the Trias (see *op. cit.* fig. 2, p. 123, and fig. 9, p. 135). According to Kilian the presence of the 'schistes lustrés' seems to exclude the presence of the Carboniferous, and he therefore suggests that the 'schistes' may be Carboniferous; though he admits that this cannot be definitely determined. If, however, Zaccagna and Lory be correct, and the central rocks of Mont Jovet are 'schistes lustrés,' then these occur surrounded by both Carboniferous and Triassic rocks. In that case, it cannot be maintained that the 'schistes lustrés' are the eastern metamorphosed condition of the beds which farther west have remained as non-foliated sediments.

The identification of any 'schistes lustrés' in Mont Jovet would therefore alone be fatal to the view that these rocks are Carboniferous or post-Carboniferous in age. Having failed on previous occasions to obtain definite proofs of the pre-Carboniferous age of the 'schistes lustrés' in the Cottian Alps, I was the more impressed by Bertrand's reversion to Lory's theory. The perusal of Bertrand's paper did not carry conviction; but respect for the care and ingenuity with which the author had solved the puzzling problems of Provençal geology necessitated the careful consideration of his views. I therefore resolved to visit Mont Jovet as soon as the melting of the snow rendered geological work possible, and examine the mountain independently in order to see whether it does contain any 'schistes lustrés'; and, if so, to try to construct a more detailed geological map than has yet been published. So much, however, of the mountain is covered by pine-forest and talus, by moraine and meadow, and so many of the important junction-lines are thus hidden, that it was impossible to make a geological map sufficiently complete to repay the time which it would occupy. I had therefore to be content with a sketch-map based on the French Ordnance survey on the scale of 1:80,000.<sup>1</sup>

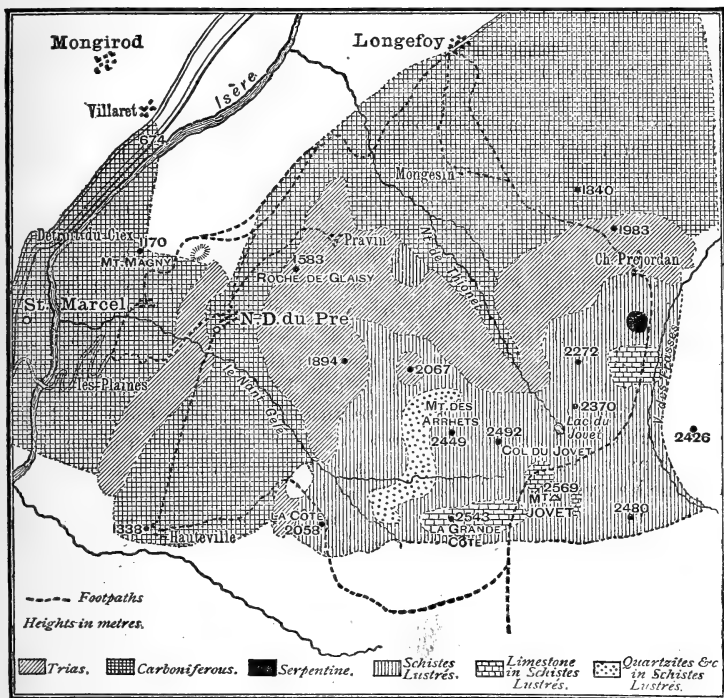
Standing on the hills on the northern side of the Isère, at any good point of view between Moutiers and Aime, the southern side of the valley is seen to consist of three main divisions. The lowest part is formed of steep cliffs of dark-coloured rocks, covered by vineyards, meadows, and woods. Above this is a belt of pine-forest; in this occur at intervals cliffs of buff dolomite and white gypsum, and occasional crags and pinnacles of the former rock. Above this belt are the high-level pastures, formed of undulating meadow-land passing up into irregular rock-strewn slopes, and a group of peaks, of which the highest is Mont Jovet. Further examination of this mountain-mass shows that these three zones are each formed by different series of deposits. The lower slopes are occupied by Car-

<sup>1</sup> Albertville, S.E. feuille 169 *bis*, type 1889.

boniferous; the cliffs above by Triassic dolomites and gypsums; the highest meadows and the central peaks by the rocks whose age is in dispute.

The area more especially examined was the north-western quadrant of the mountain, which is included in the sketch-map, fig. 1.

Fig. 1.—Sketch-map of the north-western quadrant of Mont Jovet.



Scale:  $\frac{1}{80,000} = .792$  inch to the mile.

The Carboniferous rocks are of the ordinary type of this series in the Tarentaise; good sections and exposures can be seen on the banks of the Isère, and around the hamlets of Hauteville and Notre Dame du Pré, at the height of 2500 feet above the floor of the valley. The superposition of the Triassic rocks to these can be clearly seen around the latter village, for the Carboniferous beds there form a platform upon which the Triassic limestones rest.

It is unnecessary to give any description of the characters of the Carboniferous and Triassic rocks, but those of the third series require more careful notice. For the question as to whether or no these are part of the 'schistes lustrés' can be determined by lithological evidence alone.

The rocks in question consist of three main types: 1st. A series

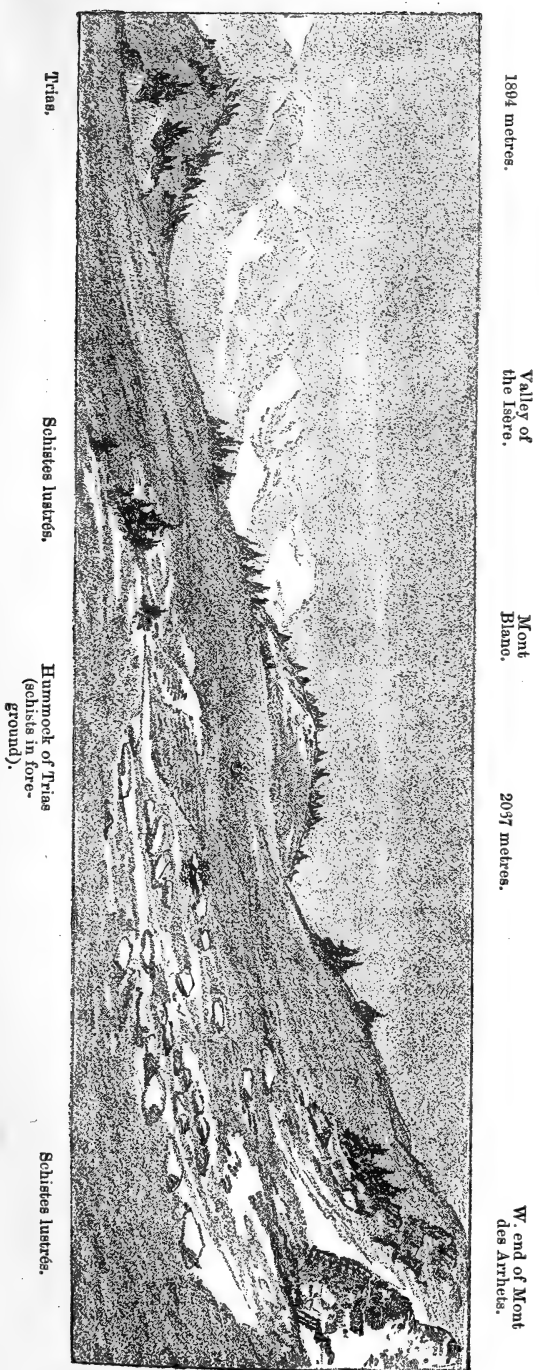
of limestones sometimes massive, sometimes passing into calc-schists, the beds of which are separated by beds of crushed phyllites; 2nd, gritty quartzites and irregular quartzitic schists; and 3rd, talcose lustrous schists. These three sets of rocks occupy the whole of the central part of the mountain, including the summit of Mont Jovet and the four subordinate peaks, namely, the Grande Côte (2543 metres), La Côte (2058 m.), Mont des Arrhets (2440 m. and 2492 m.), and the ridge including the 2272 and 2370 metre-points north of Mont Jovet, between the upper valleys of Nant de Thionet and the Vallon des Frasses. The main problem is the relation of this group of rocks to the Trias upon its margin.

The position of the junction of the Triassic limestones and the rocks of this central series, or, as we may at once, for convenience, call them, the 'schist series,' can be easily determined to within a few yards. The actual junctions, however, are hidden. I did not, in fact, find a single case where, in a clear cliff-section, the actual superposition of the two could be seen. In several points, as at the junction of the gypsum and the schists in the hollow between the 2067 metre-point and the western end of the Mont des Arrhets, it certainly appears as if the Trias underlay the schists; for the apparent dip in the gypsum is to the south-east, and under the schists. It is not, however, certain that this bedding in the gypsum is true stratification; but even if this be so, the apparent superposition can be explained as due to an overfold, or to the subsidence of the limestones, owing to the solution of the gypsum along lines of drainage. The latter cause has certainly rendered the apparent dip in the gypsiferous beds very unreliable.

The most instructive case illustrating the relation of the two series was found a little to the north-west of the western end of the Mont des Arrhets. There occurs a hummock of the gypsiferous part of the Trias, marked on the map as the 2067 metre-point. The stratigraphical relations of this mass are clear, for the junction between it and the schists can be traced all round, excepting for a few yards on the north-eastern side. The evidence is sufficient to show that this hillock is simply a mass of the Trias, left as an outlier on the flanks of a slope of schists.

The relations of this Trias are illustrated by the accompanying sketch (fig. 2). The fir-covered boss in the centre is the 2067 m. point; the lower knoll to the left (the 1894 m. point) is the upper termination of the main outcrop of the Trias. On the extreme right is a low cliff of schist, which is part of the western end of the Mont des Arrhets. The schists can also be seen in some low crags on the eastern side of the valley, to the right of the 1894 m. hill. They can moreover be traced over the whole of the grassy slope from the end of the Mont des Arrhets, round the southern side of the 2067 metre-boss, to the valley to the west, and thence up the lower part of the slope of the 1894 m. point. Fortunately, the ground on the southern side of the 2067 m. point is *moutonnée*, and the crests of the ridges either just reach the surface, or can be exposed with but little trouble. It is thus possible to prove that the schists

Fig. 2.—Sketch of Dolomite-outlier at the foot of the western end of Mont des Arhuts (seen from the cow-chais of Notre Dame du Pré, looking northward).



are continuous from the end of the Mont des Arrhets, round the Trias outlier, to the crags in the valley below, where they finally plunge under the main sheet of Trias. On the northern side of this boss of dolomite there is a very steep slope down to the Nant de Thionet. The upper part of this slope is masked by pine-wood and talus, and outcrops of rock *in situ* are very scarce. The complete isolation of the limestone-boss cannot therefore be proved. The general characters of the cliff to the north leave no doubt in my mind that it is wholly formed of schists; all the exposures seen were of rocks of this series, and these were sufficiently numerous to restrict the possible connexions between the dolomite of the boss and that of the cliffs below to a very narrow band. This band would run almost at right angles to the strike of the schists, and thus can only have been formed by deposition upon these. Its existence, therefore, would strengthen the evidence in favour of the view that this dolomite is an outlier from the limestones below, from which it has been separated by denudation. In this case the sheet of limestone of which it was once a part must have been deposited on the flanks of the old schist series.

A second line of enquiry is as to the occurrence of fragments of one formation in the other. It is natural to turn to this for assistance, for one definite case would settle the question. In the schist series there are some crushed grits which must formerly have been fine pebble-beds. I searched in these in vain for any fragments of the dolomite. In the Trias there are bands of conglomerate, crowded with included fragments. The first of those examined was at the Chalets du Préjordan; a small pit there yielded numerous fragments of what appeared to be altered dolomitized specimens of the limestones in the central schist series. I could not, however, there find any unquestionable specimens of the 'schistes lustrés' themselves. At a point near Notre Dame du Pré more satisfactory evidence was obtained. The Triassic dolomites there contain some beds of pebbles, many of which appear to me to be unquestionable fragments of the 'schistes lustrés.' Some of these included fragments may be matched exactly in the cliff of schists, just above the bank of limestone in which the fragments occur.

A third line of argument may be based on the unaltered condition of the Triassic rocks in contrast with those of the central schist series. The Triassic dolomites show no sign whatever of foliation. Bertrand has remarked the intensity of the puckering and folding of the rocks of the centre of the massif, and admits that this is not easy of explanation. Lory had previously recorded the occurrence of albite-crystals in the limestones of the schist series, but regarded this as only an illustration of the extent to which the Triassic rocks have undergone alteration. If the metamorphism of the schists were most strongly marked in the centre of the massif, and least so on the margin, it might be explained as due to post-Triassic movements. But this is not the case. The extent to which the rocks have been rendered schistose depends on the character of the rocks and not on their position. Some of the rocks in which the foliation is most marked occur on the margin of the series within 10 yards of the dolomite.



On the other hand, the member of the schist series which at first sight appears least altered is the massive limestone of the Grande Côte, nearly in the centre. Even between the least altered of the limestones of the schist series and the Triassic dolomite there is a great difference. Microscopic examination shows that the latter is a normal dolomite, and does not contain any authigenous crystals of albite. The limestones of the schist series, on the other hand, are really calciphyres, show traces of intense crumpling, and contain abundant crystals of plagioclase and epidote. If the schists be really younger than the Trias, it appears inexplicable why these should have been so intensely altered, while the dolomites in contact with them should have escaped.

It is therefore contended that the evidence is conclusive that the Triassic dolomites have been deposited unconformably on the edges of an older series of schists. It remains now to consider what evidence is available to determine with which member of the schist series in the Western Alps these must be correlated. The contorted, lustrous, black, talcose schists which occur on the summit of Mont Jovet remind one at once of the 'schistes lustrés' of the classical area around Cesana, *i. e.* of the 'Kalkschiefer' of Diener, the 'Calcescisti' of the Italian geologists, or the 'Upper Archæan schists' of Prof. Bonney. Zaccagna—whose acquaintance with these schists is intimate—has no hesitation in regarding these as part of this series. Lory, who knew both series extremely well, also unhesitatingly identified the Mont Jovet rocks as 'schistes lustrés.'

It must be admitted that in one respect these rocks are not typical representatives of the 'schistes lustrés' series, and that is the great development of massive limestones and quartzitic beds. Bands of the same character as these occur in the 'schistes lustrés' around Cesana; but both the limestones and grits are there represented by very thin layers and films, and the main mass of the formation consists of black lustrous schists.

It is these massive limestones which Bertrand has assigned to the Lias, and macroscopic examination of a specimen does not show anything fatal to this view. Microscopic study, however, reveals the fact that the rocks are entirely crystalline, and have undergone intense alteration. Sections of specimens from a boss in the upper part of the valley of the Nant Gelé, on the northern slope of the Grande Côte, and from the summit of this peak, show that they consist in the main of crystalline, polysynthetically twinned calcite. A black carbonaceous dust occurs in irregularly crumpled and broken lines through the rock. Some small grains of plagioclase (determined by Lory as albite) are scattered in the calcite at irregular intervals. Grains of epidote are fairly numerous. The rock is therefore a calciphyre, and is very different in structure from the Jurassic limestones of the neighbourhood.

The black lustrous schists, with which these limestones are seen to be interstratified both on the central peak of Mont Jovet and on the flanks of the Grande Côte, are, however, thoroughly typical

'schistes lustrés.' A specimen collected on the western arête of Mont Jovet, just below the summit, agrees in its microscopic structure with the schists of the Cesana district. The microscope shows that it consists of alternate layers of a black, indeterminate, and a clear crystalline material. The rock is intensely crumpled, and the black bands often thin out along lines of shear. A quarter-inch objective resolves the black material into a very fine calcareous and argillaceous dust, and the white clear layers into a mosaic of quartz in which occur tiny crystals of white mica. There is no sign of calcite in the rock, nor does it effervesce with acid. The rock, therefore, agrees exactly with one of the finer and non-calcareous varieties of the 'schistes lustrés' of the Cottians.<sup>1</sup> It appears to have been originally a fine-grained mudstone.

It may be suggested that possibly the 'schistes lustrés' and the limestones are not part of the same series. But that they are so is very clearly shown just below the summit of Mont Jovet. A few yards along the ridge to the east a layer of limestone strikes right across the ridge. Some rocky ribs run down the northern face at this point, and in one of these, about 30 yards east of the summit, the junction can be clearly seen. It could not be traced far, as there was too much snow on this face of the mountain at the time of my visit; but the exposures were sufficient to demonstrate the interstratification of the limestones and the schists.

In spite, therefore, of the unusually extensive development in the schist series of this massive non-foliated limestone, I feel bound to admit that Lory and Zaccagna were right in identifying the central rocks of Mont Jovet as 'schistes lustrés.' There is nothing at all improbable in the outcrop of these schists in Mont Jovet, if they be pre-Carboniferous in age. This series is extensively developed 15 miles to the east and 20 miles to the south, and its extension thence westward below the Carboniferous and Trias rocks, as suggested in Zaccagna's section,<sup>2</sup> is not in any way improbable.

Another feature which allies the rocks of Mont Jovet to the crystalline schist series, is the occurrence in them of basic igneous rocks of the 'pietre verdi' type. These have been recorded on the mountain by Favre, as well as by Zaccagna and Bertrand. A mass of serpentine occurs in the schists in the upper part of the Vallon des Frasses: it appears almost identical with that described by Bonney from the pass of Mont Genève, which has been proved to be pre-Triassic.<sup>3</sup> I should be loth to use the characters of intrusive igneous rocks as a proof of age, but the coincidence in this case is significant.

<sup>1</sup> It may be compared with Prof. Bonney's description of the microscopic structure of the 'schistes lustrés' near Cesana, Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 103.

<sup>2</sup> Zaccagna, 'Riassunto Osserv. Geol. Alpi Graie,' Boll. R. Com. geol. Ital. vol. xxiii. (1892) pl. v. sect. 2.

<sup>3</sup> T. G. Bonney, 'Two Traverses, etc.,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 80; Cole and Gregory, 'Variolitic Rocks of Mont Genève,' *ibid.* vol. xlv. (1890) p. 305; Davies and Gregory, 'Geol. Monte Chaberton,' *ibid.* vol. l. (1894) p. 307.

## CONCLUSIONS.

It is contended, on the evidence above cited, that Lory and Zaccagna were right in identifying the central rocks of Mont Jovet as 'schistes lustrés,' for this conclusion is supported by their lithological characters and the nature of the igneous rocks associated with them, and is not opposed to their stratigraphical relations.

It is further shown that the schists in question are older than the Trias (1) by the occurrence of fragments of the schists in the Trias; (2) by the discordance of strike between the two series; (3) by the occurrence of masses of dolomite resting unconformably on the flanks of the schists; and (4) by the fact that the Trias has escaped the metamorphism which the schists have undergone.

The probabilities are all in favour of the schists occupying the same relation to the Carboniferous as they do to the Trias; while the close approximation of the schists to the former show that the schists are not the altered representatives of the Carboniferous. We must therefore conclude that the 'schistes lustrés' are pre-Carboniferous, but evidence by which finally to assign them to any exact horizon before this date is still wanting.

## DISCUSSION.

Prof. BONNEY expressed his sense of the great value of Dr. Gregory's paper, which he regretted had been pushed into a corner by the time which he had been obliged to take up for his own. From his general knowledge of the district and intimate acquaintance with other parts of the Alps, he had no doubt that Dr. Gregory was quite right in his interpretation, and that the crystalline schists, often called the 'schistes lustrés,' were certainly pre-Carboniferous, and probably much older.

Dr. DU RICHE PRELLER fully agreed with Prof. Bonney's remarks as to the great importance of the subject dealt with in the paper, and was gratified to see that the Author substantially endorsed the views of Zaccagna, who had done so much excellent work in the Western Alps from 1887 to 1889, and, by extending the survey on the Italian side for fully 30 miles into the Vanoise district in Savoy, as far as the valley of the Isère, had conclusively shown that Lory's views as to the Upper Triassic age of the calcareous schists, or 'schistes lustrés,' were utterly untenable, and, further, that the bulk of the mica-schists referred to by Termier as Permian are also, like the 'schistes lustrés,' pre-Carboniferous—indeed, of Archæan age. The speaker had visited the Savoy district some years ago, and, in his opinion, the occurrence in the central mass of Mont Jovet of serpentine, gabbro, and so-called green Alpine marble (as quarried near the summit), under conditions strictly analogous to those on the Italian side near Susa, and also in Liguria, affords a strong argument in favour of the Savoy 'schistes lustrés' being, like those of the Italian localities, of Archæan age.

The AUTHOR replied, thanking the Fellows for their reception of his paper.

2. ADDITIONAL NOTES *on the TARNs of LAKELAND.* By J. E. MARR, Esq., M.A., F.R.S., Sec.G.S. (Read November 20th, 1895.)

THE following notes form a supplement to a paper on 'The Tarns of Lakeland' read before the Society in 1894.<sup>1</sup> I have had the opportunity during the present summer of devoting more time to the study of Watendlath Tarn, and have examined three other tarns of some interest.

(a) Watendlath Tarn.

In my former paper, I stated that in the case of Watendlath Tarn 'a great mass of drift is plastered against the east side of the valley, and may have filled the old valley.' I have since ascertained that there is no old valley there, but that the solid rock runs all round the northern, eastern, and southern ends of the tarn: I furthermore stated that 'on mounting some way above the tarn I saw indications of the possible existence of a moraine-filled depression' on the western side. I have now examined this depression and satisfied myself that beneath it lies buried the old valley, the stream from which ran down into Borrowdale near Rosthwaite—that is, about 3 miles south of the present junction of the Watendlath valley with Rosthwaite, near Lowdore. This moraine-filled depression runs close to the path from Rosthwaite to Watendlath Tarn. The watershed here is about 200 feet above the surface of the tarn, and, as the tarn is 46 feet deep, it requires a barrier of drift over 250 feet in thickness to account for the tarn; but, as the valley is evidently a narrow one, and its course lay at right angles to the direction of the ice, the occurrence of this somewhat thick mass of drift presents no difficulty, and a much thicker mass has been recorded in the neighbourhood filling up an old valley, as proved by boring in Furness.

Proceeding from Rosthwaite towards the tarn, the path ascends by the side of a stream running from Brund Fell to a spot called Birkett's Leap, where it leaves the main stream and is carried parallel with a tributary descending from the lowest part of the watershed. The stream from Brund Fell and the lower part of the tributary stream have cut to a considerable depth between rock and drift, the northern bank of the stream being composed of rock, and the southern side of drift, so that the streams appear to be gradually cutting out the old valley (see fig. 1). To the east of Birkett's Leap,

<sup>1</sup> Quart. Journ. Geol. Soc. vol. li. (1895) p. 35. In this paper the following errata occur:—

Page 39, last line, *for 'Ask' read 'Ark.'*

„ 42, line 7 from bottom, *for 'lower' read 'southern.'*

„ 42, line 8 from bottom, *for 'upper' read 'northern.'*

„ 44, line 7 from top, *for 'east' read 'west.'*

„ 45, line 5 from bottom, *for 'east' read 'west.'*

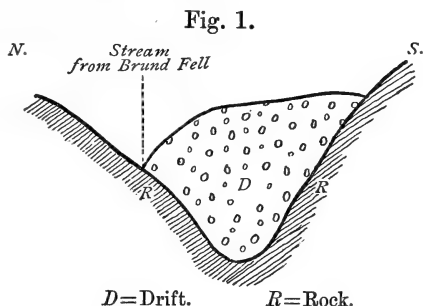
the tributary crosses to the southern side of the drift-filled depression, and east of this the rock lies on the southern, the drift on the northern bank. At the top of the pass, the path is on the northern border of the drift-filled depression, which is readily traceable towards the tarn. Some way below the top of the pass on the Watendlath side, a stream called Bowdergate Gill runs along the depression, and has cut a ravine in it, which is well wooded towards the tarn. In some places this ravine is about 50 feet deep, and is cut entirely through drift, with drift forming the bed of the stream.

It may be noted that on looking towards the eastern side of Borrowdale from below Rosthwaite, the col above-mentioned is the only place where solid rock is not visible against the sky-line for a distance of about 2 miles, and it is also the lowest portion of the sky-line in this space.

There are indications of an old terrace some way above the present surface of the tarn, which are most clearly seen on the eastern and southern sides. This probably marks the original height of the old col between the former Watendlath and Lowdore valleys, which would form the exit of the lake after the stoppage of the narrow Watendlath-Rosthwaite gorge, the rocky ravine just below the tarn having since been deepened to the extent indicated by the difference of level between the present surface of the tarn and the summit of the old terrace.

### (b) Hard Tarn, Helvellyn.

In his paper on 'The Glaciation of the Southern Part of the Lake-District and the Glacial Origin of the Lake Basins of Cumberland and Westmoreland,'<sup>1</sup> Clifton Ward remarks (p. 161):—'Just below and south of Nethermost Pike, Helvellyn, in Ruthwaite Cove, is Hard Tarn, 150 feet by less than 100 in size; it is very shallow, so that one can see the rocky nature of its bed and sides, and mark how the ice-scratches pass beneath the water from one side to the other.' Owing to the above statement and to the small size of the tarn, which might well be a rock-basin, even if the other tarns of the district are only drift-dammed, I was particularly anxious to see this lakelet, but was prevented by bad weather in former years. This year I had an opportunity of examining it. The pond lies on a dip-slope of some ash-beds having a gentle inclination towards a steep escarpment-cliff above, which is surmounted by another dip-



<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 152.



depth from 3 to 2 feet, the tarn gradually shallowing towards the south. The normal exit is at the western end, by a stream running through screes (*E*), and although these screes form so insignificant a feature in the landscape that they might readily be overlooked, and the rest of the lake is surrounded by solid rock, actual measurement revealed the fact that the shortest distance from rock to rock near this exit was about 25 feet, so that there is little doubt that this tarn owes its existence to the blocking of one end of a sloping dip-slope between two escarpments by screes. A feature of particular interest was noticeable at the time of my visit after heavy rains. Another stream ran from the middle of the southern side of the tarn from the abnormally high lake-level, over the lower escarpment, along a shallow groove. As this groove must be gradually deepened during wet periods, while the screes are increasing at the exit, the time will arrive when this tarn ceases to be one having its exit over loose material, and sends its surplus waters permanently over the solid rock. We have here an intermediate stage in the process of formation of such tarns as Codale, described in my former paper.

#### (c) Hayeswater.

I examined this large tarn lying below High Street, and south-east of Patterdale, because, in the discussion upon my former paper, it was cited by Dr. Mill as a possible connecting-link between the tarns and the valley-lakes. It lies at an elevation of 1383 feet, and the last rock seen in Hayeswater Beck, which issues from it, is near the point where the 1250 feet contour-line crosses the beck. The tarn might well be deeper than 133 feet, and still be drift-dammed, for the hill on the left bank of the gill has a thick bank of drift running far down Hayeswater Gill valley, and a buried valley of great depth might well exist beneath this. In many places, Hayeswater Beck seems to be cutting its way between rock and drift, as described in the case of the stream from Brund Fell, near Rosthwaite. Hayeswater therefore presents no indications of lying in a rock-basin.

#### (d) Angle Tarn, Patterdale.

This tarn lies on a plateau beneath Place Fell. It is evidently quite shallow, for numerous boulders project above its surface in different parts, and it is hardly likely that anyone would claim it as a rock-basin, with its numerous rocky bays, its two islands and peninsula. It was formed by the stopping of a depression starting from the northern end of the tarn, and running round the rocky knoll north of the present exit, to join the beck proceeding from this exit, a short distance west of the tarn.

## DISCUSSION.

Dr. H. R. MILL said that he was much interested in the Author's observations, especially those on Hayeswater. He wished that there were facilities in the meeting-room for optically projecting photographs, as a photograph he had taken from the top of High Street showed the glacial accumulations in the narrow valley very distinctly. As Mr. Marr had found every tarn that he examined to be held in by a barrier of drift, it seemed very likely that most, if not all, of the larger lakes would be found to owe their origin to the same cause. In this connexion it was worth mentioning that Prof. W. M. Davis, of Harvard, considered, from the configuration of the larger lake-basins in the district, that they were produced in drift-blocked valleys.

The AUTHOR thanked Dr. Mill for his remarks. He observed that even if Hayeswater were abnormally deep for mountain-tarns, there was sufficient drift to block it. He had already written a paper on the origin of the larger lakes of Lakeland, and submitted it to another Society.



3. *The SERPENTINE, GNEISSOID, and HORNBLLENDE ROCKS of the LIZARD DISTRICT.* By T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read November 6th, 1895.)

## [PLATE I.]

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## I. INTRODUCTORY.

IN 1891 a communication on the rocks of the Lizard from General M<sup>c</sup>Mahon and myself was honoured with a place in the Society's Journal.<sup>1</sup> As therein stated, we were of opinion, at the time of our visit to Cornwall (August, 1890), that to regard the banded members of 'the hornblendic group' as stratified basic tuffs, subsequently metamorphosed, was 'the better working hypothesis.'<sup>2</sup> But, even in that interval, as will be seen by a note appended to the paper,<sup>3</sup> some doubts as to the correctness of this conclusion had already arisen in my mind, for a visit to Sark in the spring of 1891 had suggested explanations of certain difficulties which hitherto had seemed insuperable in an alternative hypothesis. Accordingly I became anxious to see how the old puzzles looked in the new light, and besides this a very important paper by my friends Messrs. Howard Fox and J. J. H. Teall,<sup>4</sup> subsequently published in this Journal, made it a necessity for me to study the sections of which they had given so lucid a description. For, if their interpretation of these were correct, the geology of the crystalline rocks of the Lizard peninsula would be thrown (as it seemed to me) into hopeless confusion. The authors, indeed, restricted their conclusions to the sections which they had described; but it appeared to me, for reasons which will be given hereafter, that no such limitation was possible, and that if they were right I must have misinterpreted the evidence in other localities. I felt, indeed, so much confidence in the general

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 464.

<sup>2</sup> *Op. cit.* p. 480.

<sup>3</sup> *Op. cit.* p. 479.

<sup>4</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 199.

accuracy of my observations that under ordinary circumstances I should have deemed it needless to revisit the district; but when two such critics, the one so keen an observer, the other so skilled a petrologist, both entered the lists against me, though in the most friendly contest, I felt compelled to take the first opportunity of revising my work. This was done in the summer of 1894. Other engagements unfortunately prevented Gen. McMahon from giving me the pleasure and the benefit of his company, but I had the great advantage of the society and co-operation of the Rev. E. Hill, with whom I have so often worked in this and other regions, and to whom I tender my best thanks for constant aid. [He has kindly read a proof of this paper, and requests me to say (as I do most gladly) that he can confirm all the statements as to what was seen in the field.]

Going first to St. Keverne, we succeeded, as we hope, in clearing up a minor difficulty, which our former visit had failed to solve, and we reviewed the hornblende-schists of this neighbourhood. Then, in a fortnight's hard work, from Lizard Town as a centre, we carefully studied all the sections, as far as Mullion Cove on the west and Kennack Cove on the east, which seemed likely to throw light on the problems specially before us: namely, the genesis of the hornblende-schists and of the so-called 'granulitic group,' and the relations of these rocks to the serpentine and to certain other rocks of igneous origin, but less altered than it. The former problem need not be discussed at any great length, though we accumulated a large number of observations, bearing upon it. The latter one in reality involves the whole question of the relations of the crystalline rocks in the Lizard district, and so demands a rather full treatment.

## II. THE GENESIS OF THE HORNBLLENDE-SCHISTS.

It will suffice to refer to former papers for descriptions of the petrography of this interesting group. As to the facts, I believe that Messrs. Fox and Teall, Gen. McMahon, and myself are practically in accord.<sup>1</sup> From the neighbourhood of the lighthouses near Lizard Town to Pollurian Cove on the west (a distance in a straight line of about 5 miles) and to Porthallow Cove<sup>2</sup> on the east ( $9\frac{1}{2}$  miles), this group, whenever it appears, exhibits substantially the same characteristics. It varies from a dark rock, more or less speckled with white, sometimes so little foliated as to be barely distinguishable from a diorite, occasionally even retaining slight indications of an ophitic or of a porphyritic structure, to one which is clearly foliated and sometimes well banded: dark hornblendic layers alternating with those of a whitish or of a yellow-green colour, the former being rich in feldspar, the latter in epidote. The more banded varieties occasionally exhibit a structure which curiously resembles

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 1, vol. xlv. (1888) p. 309, vol. xlv. (1889) p. 519, vol. xlvii. (1891) p. 464.

<sup>2</sup> I adopt the spelling of the 6-inch Ordnance map; formerly it was Porthalla, as in previous papers.

false or current-bedding.<sup>1</sup> This, as stated in our paper of 1891, was difficult to explain on any other hypothesis than that of an original stratification, which also accorded very well with the aspect of the banded rock. Doubts, however, as mentioned in the paper on Sark by Mr. Hill and myself,<sup>2</sup> had arisen as to the validity of these difficulties, and proof had been obtained that distinct mineral banding might occur in a true igneous rock of like composition,<sup>3</sup> so that the whole question was investigated *de novo*. Three localities appeared to supply evidence of special importance, which I shall endeavour to describe.

### (a) Inclusions in the Hornblende-schist at Porthoustock Cove.

The hornblende-schist on the northern side of this cove is sometimes very dark in colour, sometimes rather conspicuously streaked or banded with felspar: the more homogeneous and the more banded rock alternating twice or thrice, in a vertical space of about as many yards. Sometimes fairly well-formed crystals of white felspar occur porphyritically in the dark rock, up to about  $\frac{1}{2}$  inch long, sometimes the rock becomes coarser and recalls the structure of a hornblendic gabbro. Now and then<sup>4</sup> the latter rock forms a kind of 'eye' in the normal banded schists and presents a structure resembling current-bedding (fig. 1). But rather towards the western

Fig. 1.—One of four 'eyes,' consisting of a coarse, gabbro-like material in the normal hornblende-schist. (North of Porthoustock Cove.)



end of the Cove we found an inclusion of nearly pure, rather coarsely crystallized hornblende. It is about 6 or 7 inches thick in the part drawn (fig. 2, p. 20): the ordinary hornblende-schist bending round it, as indicated, but it 'trails out' to the right and, interruptedly (there are two layers), to the left. In this direction, at about the same level, are two or three similar but smaller inclusions. A slice from the largest inclusion<sup>5</sup> shows it to consist almost entirely

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 4; see pl. i. fig. 2.

<sup>2</sup> *Ibid.* vol. xlviii. (1892) p. 122.

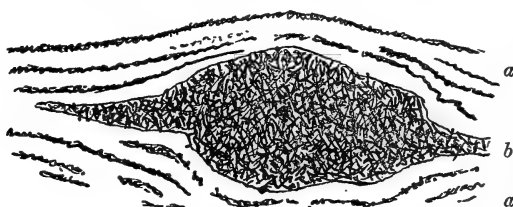
<sup>3</sup> *Op. cit.* pp. 134-138, *cf.* p. 124.

<sup>4</sup> I saw about four instances—varieties of linear streaking were countless.

<sup>5</sup> The specific gravity of the specimen, as determined with a Walker's balance, is 3.124; the mean of two specimens of fairly normal hornblende-schist is 2.748. I am indebted to Miss Raisin for these and other determinations in this paper. To ensure accuracy, each of us read the balance.

of a dull green, rather strongly pleochroic hornblende, in somewhat irregularly-formed crystals, commonly much speckled with minute and elongated specks of iron oxide. Some larger granules of the latter mineral occur, with a little rutile and possibly pseudobrookite. Besides, there are a few isolated grains or granular patches of a clear

Fig. 2.—*Eye of hornblendite, included in banded hornblende-schist.*  
(Northern side of Porthoustock Cove.)



*a* = banded hornblende-schist.  
*b* = coarsely crystallized hornblende.

mineral: this has rather a high refractive index and low polarization-tints for a felspar, an extinction, I think, oblique (it is difficult to get any line from which to measure), and it may perhaps be a colourless epidote. These inclusions, though on a much smaller scale, recall to mind those which we found so common in Sark.<sup>1</sup>

(b) Inclusions in the Hornblende-schist south of Kilcobben Cove.

Here also the rock is frequently streaked, and instances of resemblances to current-bedding are by no means rare. Near to the northern side of the promontory we found long lenticular masses of rather coarse hornblendic rock, such as is described above, lying with their flat sides roughly parallel with the dominant banded structure. They are seldom more than 2 or 3 inches thick, but are sometimes 2 or 3 feet long and almost as wide.<sup>2</sup> From this size they may be found down to little patches, almost streaks.

(c) Quarry on the descent to Mullion Cove.

This quarry, noticed in the paper of 1891,<sup>3</sup> was in a better condition for study at the time of our visit in 1894. The rock here is generally coarser in structure than any other mass known to us in the Lizard peninsula. Most of it shows a banded structure, which,

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlviii. (1892), p. 128, etc.; see also vol. xliii. (1887) p. 324.

<sup>2</sup> In a slice from one of these I find nothing but hornblende, like that described above, and a little iron oxide. But the rock was very difficult to cut, and the slice is a rather thick one.

<sup>3</sup> *Op. jam cit.* p. 479.

however, here and there disappears, for it passes into a 'spotty' one. But the general condition of comparatively coarse crystallization is replaced, locally and rapidly, by a finer one; the latter exactly resembling the normal hornblende-schist, whether banded or 'dioritic,' which occurs elsewhere at the Lizard. Fine-banded and coarse-banded portions may be seen, one within a foot of the other. Of the latter variety, bands, quite  $\frac{1}{4}$  inch thick, consisting almost wholly of felspar, can be traced frequently for more than a foot in length; bands also, both light and dark, sometimes quite  $\frac{1}{2}$  inch thick and occasionally more, run continuously for 8 or 9 inches at least. One part of the rock presented a curious resemblance to false bedding, but a closer examination showed that this might be equally well produced by a shearing movement in the mass. In another place the bands were overfolded, and appeared to have become displaced by a 'strain-slip' movement. The latter, no doubt, might be produced after the solidification of the rock, but the general appearance of the former structure and the absence of divisional planes suggested that it was due to a sliding movement, while the mass was still more or less viscid, so that the ruptured surfaces had become cemented during the last stage of crystallization. The irregular and sporadic passage from the banded to the spotty condition also seemed difficult to explain if the former were due to an original stratification of clastic materials, but seemed easily explicable on the hypothesis that movements had taken place in a magma, after some constituents had separated, but anterior to the complete crystallization of the mass; this had caused the ordinary 'granitic' structure of a holocrystalline rock to be replaced in many parts by a banded one.

It has, however, been suggested that these linear structures are due to a yielding—more or less local—in a coarse holocrystalline rock when subjected to pressure. Apart from considerations which I have elsewhere noticed,<sup>1</sup> I had this hypothesis always before my mind and found it inapplicable as a general explanation, though I should admit the possibility of its accounting for a certain 'slabiness' occasionally perceptible.<sup>2</sup> The effects of dynamo-metamorphic processes, in the ordinary sense of that long word, can be studied at the extreme south and in a more limited area at Porthallow, as described in our former paper, and the conclusions then formed were strengthened on the present occasion by tracing, especially in the first-named district, the gradual change from the normal hornblende-schist to the pressure-modified 'green schist.' If then the ordinary banded hornblende-schist of the Lizard owes its structure to 'dynamo-metamorphism,' recrystallization must have subsequently occurred to such an extent as to destroy every characteristic of that process. To concede this, I may observe by the way, would be fatal to every attempt to implicate the schist and the serpentine in an 'igneous complex,' for the latter rock, as a rule, exhibits no sign of

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 94, and vol. l. (1894) p. 279.

<sup>2</sup> But, even if this be due to a very slight shearing, its parallelism with the banded structure and consequent low hade (universal features, so far as I know) are by no means easy to explain.

crushing or of recomposition, whether as serpentine or as peridotite. The breadth and persistency of the bands in this hornblende-schist, as I have more than once pointed out in similar cases, are further difficulties in the dynamo-metamorphic hypothesis. In order to obtain by crushing bands such as those described above, the original rock would have had to be almost incredibly coarse; yet such bands are not infrequent both at the Lizard and in Sark.

As regards the 'stratification' hypothesis which I formerly accepted, I may mention a difficulty, the gravity of which has increased with my experience. If the rock originally were a basic tuff (and no other materials would give us the appropriate chemical composition), the conditions of deposit must have been very exceptional. Undoubtedly, beds of fine-grained ash occasionally exhibit great regularity of structure, but commonly this is speedily interrupted by the setting in of coarse material, the rock becoming 'knubbly' if not agglomeratic. But these hornblende-schists are singularly free from blotching or irregular spotting<sup>1</sup>; the bands of different mineral composition alternate just as the arenaceous and argillaceous layers at Morlaix in Brittany or Port Erin in the Isle of Man. This difficulty might, indeed, be eluded by supposing the materials to have undergone metamorphism so extreme as to dissociate the constituents of the bits of tachylyte and the lumps of scoria, and that to have been followed by an orderly process of segregation somewhat analogous to what occurs in the formation of flint, converting ultimately the rather heterogeneous materials into fairly uniform mixtures of minerals not at all minute. This hypothesis, however, though obviously a possible one, obliges us, as I feel more and more strongly, to assume conditions which are so exceptional that they can hardly have prevailed over such large areas. Hence I am forced to adopt the other hypothesis.<sup>2</sup>

### III. THE GENESIS OF THE 'GRANULITIC GROUP.'

On this subject fewer words are needed. I may content myself with saying that the result of this visit has been to strengthen my confidence in the correctness of the explanation adopted in our last paper,<sup>3</sup> namely, that these banded rocks have been produced, as probably most banded gneisses have been produced, by fluxional movements in a heterogeneous magma; the cause of heterogeneity in this case being, as in the one described in Sark,<sup>4</sup> the intrusion of an acid into a more basic rock, by which the latter has been

<sup>1</sup> The nearest approach to this is the case near Mullion Cove, described above, and even here there is nothing resembling the irregularity which is usual in volcanic ashes.

<sup>2</sup> It also accords better with that which is now generally adopted for the granulitic group. This is supposed to be almost in the condition which it assumed on consolidation; but its darker member is sometimes not very different from corresponding parts of the hornblende-schist, so that one can hardly assume the two rocks to have had totally diverse origins.

<sup>3</sup> *Op. cit.* vol. xlvii. (1891) p. 477.

<sup>4</sup> *Op. cit.* vol. xlviii. (1892) p. 132.

softened, drawn out, and even locally melted down and absorbed by the former. One section, which I found on the southern side of Kennack Cove, so well illustrates this process that it deserves, perhaps, a brief description. A light-greyish granite is intrusive into a dark dioritic rock, which it has shattered into a breccia, but in places one can see that the latter is locally melted by and incorporated with the former, the result being a regular, rather fine-grained, streaked or banded gneiss.<sup>1</sup> I obtained specimens of all three rocks and have examined them under the microscope. The granite consists mainly of quartz and felspar, with a rather small amount of biotite (somewhat bleached).<sup>2</sup> The structure is granular, only one or two of the larger felspars showing any approach to a crystal-outline, and the grains differ much in size. It exhibits the association of this mineral and the quartz to which I have often called attention as more characteristic of a gneiss than a normal granite,<sup>3</sup> with a very slight approach to a linear order in the constituents. The dioritic rock consists of felspar, rather decomposed, apparently plagioclastic, green hornblende, biotite (not much, and rather sporadic), with a little sphene, etc. The structure is granular, with occasionally an approach to ophitic, and felspars, 4 or 5 times the diameter of the rest, occur sparsely. The banded gneiss has a general resemblance in structure to the granite, except that its felspars are even more variable in form and size, the linear ordering of the constituents is more marked, and grains with micropegmatitic structure, which are rare in the other rock, are common here; apatite is more conspicuous and two or three very small garnets occur; there is a considerable amount of a rich brown biotite, but hornblende is absent; at least I do not find a single scrap (there are a few green flakes) that I can identify with certainty. On the significance of this I have already written.<sup>4</sup>

Additional evidence, however, was obtained in regard to one point of interest. I have always believed the granulitic group to overlie the hornblendic, though I felt that the evidence in favour of this was not very strong. The latter rock usually occurs in great continuous masses, the former in more or less interrupted blocks, which, though they may be sometimes traced with but little interruption for considerable distances, are associated (always so far as I remember) with the serpentine, and occur in such a manner as to give the impression that they are fragments of a mass which it has shattered, and in some cases actually transported. In one place, however, in the crags on the south side of Cadgwith Cove, as mentioned in our former paper,<sup>5</sup> the granulitic rock appeared to be superposed on the hornblendic schist. On the last occasion, favoured

<sup>1</sup> The specific gravity of the granitic rock is 2.611, of the dioritic 2.917, of the banded gneiss 2.628: intermediate, but, as we might expect from its appearance, nearer to the first.

<sup>2</sup> In these descriptions and throughout the paper, minor details of composition and structure are suppressed, as being without significance for my main purpose.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 97, etc.

<sup>4</sup> *Ibid.* vol. xlviii. (1892) p. 132.

<sup>5</sup> *Ibid.* vol. xlvii. (1891) p. 478.

by a calm day, we closely examined, from a boat, the whole line of cliffs from Church Cove to Cadgwith. We found that, after passing the huge mass of hornblende-schist which forms the crags of Carnbarrow and the gloomy portal of Dolor Hugo, the rock, on approaching the archway leading into the 'Frying Pan,' continues, for some distance above the sea-level, to be a true hornblende-schist, but that there are, in the upper part of the cliff, several reddish granitic veins, the direction of which appears to have a rough correspondence with the structure of the former rock, while the cliff above these assumes a more 'granulitic' aspect. On the southern side of the entrance to the 'Frying Pan,' a fault, or group of faults, brings serpentine and typical 'granulite' against hornblende-schist. But, immediately beyond the archway, the headland between it and Cadgwith Cove presents the following section. The upper part of the cliff, beyond all question, consists of the granulitic rock; while the lower part, at the south-eastern corner, for a considerable height above the sea, is no less typical hornblende-schist. The two rocks gently descend in a northerly direction until, near the north-eastern angle, the hornblende-schist gradually disappears beneath the water and the mainland crags consist wholly of typical banded granulite; though even here the hornblende-schist still appears in some skerries very near to the shore. Passing round into the cove, we find that its southern side, as we formerly stated, consists mainly of the 'granulitic group,' but that near the water's edge the rock generally is a hornblende-schist.<sup>1</sup> No sharp line can be drawn between the two groups, but between the well-banded and thoroughly typical representatives of each there is usually a zone from 7 to 10 yards in thickness, rather neutral in character: veins of a reddish granitic rock, breaking, on the whole in a horizontal direction, through a dark rock which now and then resembles the basic member of the granulitic group more closely than the dark part of the hornblende-schist.

Obviously, if both these groups are igneous in origin, this superposition cannot count for much. It may, however, have the significance, that, on the assumption of the hornblendic rock being the earlier extrusion, the upper part of its mass would offer less resistance under ordinary circumstances to the passage of an intruder. Hence the phenomenon may have a bathymetric significance, if it has no other.

#### IV. RELATIONS OF THE SERPENTINE TO THE 'GRANULITE' AND TO THE HORNBLLENDE-SCHISTS.

Before discussing the group of sections near Ogo-dour and east of the Lion Rock, from which my friends have drawn certain conclusions,<sup>2</sup> I must make a few remarks upon the general principle, which, as it appears to me, is implied, if not actually enunciated in

<sup>1</sup> It is regularly banded, the white felspar and dark hornblende showing a hypophitic structure, and differs only from the most normal hornblende-schists in becoming here and there slightly micaceous.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 210.



their paper.<sup>1</sup> It amounts to this: that in an extensive district, where the rocks exhibit many difficulties and complications, each section or limited group of sections can be regarded by itself and be made the basis of induction, independently of all the others. But here, unless I mistake, lurks a fallacy, the nature of which will be readily perceived by considering a particular instance as an illustration. Suppose the question to be whether an igneous rock is intrusive into or contemporaneous with a group of sedimentaries. Suppose, further, that in 11 out of 12 sections the evidence is inconclusive, but that the remaining one gives a decisive answer on the one side or the other. Then there would be no room for further doubt. The uncertainties of the eleven would count for nothing against the positive evidence of the one section. Suppose, however, that, of the 12 sections, the evidence of four or five is rather more favourable to one conclusion; that of two makes any other highly improbable, while that of one appears to accord better with the contrary conclusion; and the remainder give no answer at all. We cannot regard the testimony of this one unfavourable witness, as if the others were non-existent. Certainly no judge, probably no jury, would act upon such a principle. The apparent conflict of evidence undoubtedly calls for a careful cross-examination of each witness, but in such a case as we have mentioned it is surely far more probable that the one section should have been misunderstood than that a contradiction should exist. The more specious interpretation does not always turn out to be the true one, and we must proceed in our attempts to learn the secrets of Nature as men who are seeking to decipher inscriptions, where the language is dead and the characters are obsolete.

It may be said, however, that the ordinary laws of inductive reasoning do not apply to this particular case, because we are dealing with an 'igneous complex.' The term undoubtedly is an attractive one; there is a certain mystery about it, but there is also, as in all mysteries, a certain vagueness. 'Complex' means a tangle, and thus is a term which fails to explain anything; to fall back upon it, is a confession of defeat and an admission that when Nature plays the Sphinx we decline to take the part of Œdipus. In the case before us, however, the authors' meaning may be inferred from certain conclusions which they have formulated.<sup>2</sup> These, briefly stated, amount to this: that in the cliff and on the adjoining shore, east of the Lion Rock, the serpentine is traversed by basic dykes, which pass locally into hornblende-schist, and besides this put on, in the thicker portions, appearances which are characteristic of the 'granulitic group'; also that there is a wedge-shaped mass of this granulitic rock, which exhibits a structure incompatible with the hypothesis that the serpentine was intruded after the mass itself became solid.

In regard to these conclusions, I may venture at the outset to make the old comment *Dolus latet in generalibus*. (a) 'The dykes pass locally into hornblende-schist.' Yes, but into what horn-

blende-schist? Is it the same as the rock which forms the great cliffs of Carnbarrow and Hot Point, of Housel Bay, and Predannack Head, not to mention other places? By no means, I should say. True, the dominant minerals are the same in both, and these dykes exhibit locally a trace of foliation. That is also true of other dykes in this region<sup>1</sup>; nevertheless, the hornblende-schist proper, as a rule, is a very different rock, even macroscopically. It is commonly more or less banded, almost always distinctly 'linear' in structure; only rarely and only very locally would there be any difficulty in distinguishing the one from the other. I find that the same holds good of the microscopic structure of the two rocks; the differences can hardly be expressed in words, but as a rule they exist. What, then, does this prove? That sometimes, if we take two hand-specimens, carefully selected from two groups of rocks, differing in age and history, we may be unable to distinguish the one from the other, because neither presents characters upon which we can fasten for that purpose. We might as well affirm that the Greek and the Latin uncial alphabets belong to the same language because certain letters in the two are identical. Has any one of these dark pyroxenic dykes in the Lizard region exhibited such a banded structure as that which occurs again and again in the 'hornblendic' group? It would be, in my opinion, just as reasonable to contend that the hornblende-schist was only a modification of the gabbro,<sup>2</sup> because now and again, though very locally, resemblances can be detected; or that all the basalt dykes of Scotland were of one age, because it is not always easy to say whether a particular one belongs to the Palæozoic or to the Tertiary era. (b) 'The dykes near the Lion Rock, in their thicker parts, sometimes resemble the granulitic group.' To this we may reply in terms similar to those already used. Once or twice a dyke may be found to exhibit some rather irregular feldspathic veins or seams. But this, so far as my experience goes, is not a very uncommon feature in districts such as the Lizard. The resemblance between the two rock-masses seems to me hardly closer than the notorious one between Monmouth and Macedon. I have found it difficult in other places to distinguish between veins of infiltration and of intrusion, yet this does not prevent me from believing that each really exists, and can be often identified. So that in this case also, while I grant that certain resemblances may be found, I deny that they are sufficient to warrant the conclusions which have been drawn from them.

### (a) Relations of the Serpentine to the Granulitic Rock.

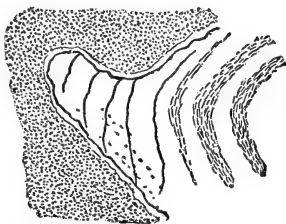
But I pass from generalities to particulars, and first to 'the wedge-shaped mass of typical granulitic rock.' There can be no question that this—like the great masses which crop up on the

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 6 (reference).

<sup>2</sup> If so, there should be no 'complex,' for the gabbro cuts the serpentine again and again.

shore some little distance to the south, belongs to the granulitic group. The drawing which my friends have given is substantially accurate<sup>1</sup>; the inference also which they draw is correct, but only in an extremely limited sense—in other words, everything turns upon the exact meaning attached to the phrase ‘solid granulitic rock.’ Taking that mass as a whole, its darker bands indicate firstly, the formation of a banded or rather a streaky structure, and secondly the contortion of the same<sup>2</sup>; but, so far as I could see, no connexion exists between these structures as a whole and the external shape of the mass, and there is nothing to difference this block from those which occur, as I have said, to the south and so often on the eastern coast. The rock is only rather curiously contorted, but this structure is not

Fig. 3.—*Projection from the granulitic mass included in serpentine. (East of the Lion Rock.)*



In all these diagrams the serpentine is dotted, and the fine lines indicate the more micaceous bands in the granulitic rock.

very uncommon in the granulitic group, and I was unable to see that any relation existed between either it or the shape of the mass and the serpentine, or to find evidence either that the granulitic rock was intrusive in the serpentine or that the two had been folded together, as the result of earth-movements while both were in a plastic condition. As is stated above, there are two large masses of the granulitic rock on the shore towards the south. These, however, are not wedge-shaped intrusions, but huge blocks; yet in places they exhibit contortions, which are hardly less pronounced than those in the other mass.<sup>3</sup> The serpentine in their neighbourhood exhibits a slight foliation, which dips at a high angle to a point a little W. of W.N.W., but this neither makes the rock fissile, nor produces any marked effect on its microscopic structure, nor stands in any relation to that of the granulitic masses.

I accordingly claim a verdict of ‘not proven’ here, and pass on to other localities to see how far their evidence is ‘incompatible with the theory that the serpentine was intruded into solid granulitic rock.’ At the first glance it seems possible to explain the

<sup>1</sup> *Op. cit.* p. 209, fig. 4. I venture to suggest two trifling emendations. At B the obtuse angle should be replaced by a blunt thumb-like projection (see fig. 3, above), and at D the serpentine occupies the wider, but not the narrower part of the inlet in the granulitic mass: the latter rock being practically continuous at a depth of 3 or 4 inches, as I could see in one place and feel with my fingers all along. To this point I shall return.

<sup>2</sup> These might be either successive stages in one process or separated by some considerable interval of time (as I incline to think).

<sup>3</sup> In these, however, the ‘dioritic’ rock predominates, so that it is granitic (lighter-coloured) bands that wriggle about.

relation of these two rocks by one of four hypotheses: (a) that the two rocks have been brought together by faults; (b) that the two have been folded together; (c) that the two have flowed together; (d) that the serpentine is intrusive in the granulitic rock.<sup>1</sup>

As the relations of the two rocks have been described in former papers, I shall not repeat what is already in print, but content myself with remarking that though I have again examined all these cases, I find no reason for altering my statements, and with describing very briefly a few other instances. As a preliminary, I venture to remind the reader that the granulitic rock commonly occurs as blocks, which sometimes appear to be completely included in the serpentine, but at others may be either projecting ridges or crags attached to much larger masses below or behind the visible surface. Where these exhibit a definite structure, this seems more or less to determine their outline, so that well-banded varieties are often fairly rectangular in shape; but as such a structure is not always present, considerable variety of form is possible. Though small slips and displacements are common in the serpentine, the faces of these blocks do not appear, as a rule, to correspond with faults; moreover, the two rocks occasionally, though not commonly, are welded together—in other words, the relations of the granulitic rock and the serpentine appear to me, as a rule, incompatible with the first or the second hypothesis. As for the third, it may be understood to mean either that the two rocks have been simultaneously emitted as parts of a magma already separated in accordance with Soret's or some other principle, or that the one material has been injected into the other, and has so completely softened it, if it were already solid, that the two have subsequently flowed on together. Now, the granulitic mass itself exhibits irregularities in structure and variations between the extremes of mineral composition, which accord well enough with the one or the other of these interpretations; but between it and the serpentine no transitional condition can be found, neither does it occur in lenticular or streak-like bands, such as the third hypothesis would lead us to expect, but in blocks; while the fourth hypothesis, as I trust will be perceived from the evidence which I am about to quote, accords better with the facts.

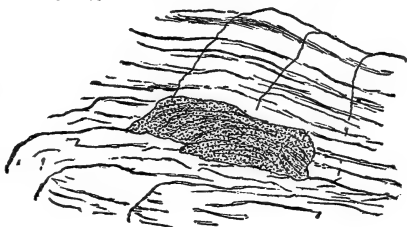
Time, however, may be saved by noticing at the outset a general objection which might not unreasonably be raised, namely that, if the serpentine be intrusive in the granulite, its relations to the latter are rather unusual. It has formed neither dykes nor branching veins in the 'granulite,' nor has it shattered that rock and caught up numerous small fragments. Yet all these are done by granite, diorite, gabbro, and other deep-seated rocks, as well as by their more compact representatives. The serpentine adopts the form, as those holocrystalline rocks often do, of irregularly-rounded bosses or somewhat elongated tongues, but it is not connected, as they very commonly are, with peripheral dykes and veins. This, however, appears to be the usual habit of peridotites and serpentines.

<sup>1</sup> I exclude that already mentioned, namely, that the granulite is the intruder, because, in the cases which I am about to mention, I cannot conceive the possibility of its being seriously entertained

I have probably examined in the field more of these rocks—especially the latter—than most geologists, yet I have never seen a branching vein, and only two or three dykes.<sup>1</sup> The mode in which this rock occurs generally suggests that it was extruded in a rather ‘pasty’ condition; sometimes also that the temperature was not very high.<sup>2</sup>

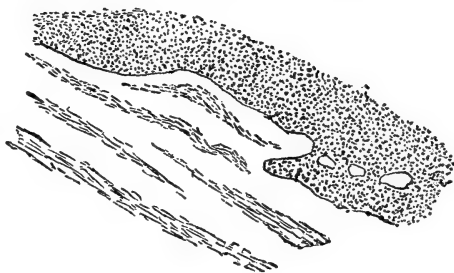
But though the serpentine does not send veins into the ‘granulite,’ its relations to that rock appear to me generally to suggest and sometimes to prove intrusion. Take, for example, this instance from Polbarrow Cove (fig. 4), where a fragment of serpentine about 14 inches long, 3 to 5 inches wide, and seemingly about 3 inches thick, still adheres to the granulite, which is particularly evenly-bedded (reddish grey with dark-coloured) for about half a yard above and a yard below. Some two or three yards behind the top of the craglet is another and longer mass of serpentine which appears to occur in a similar fashion. Or this

Fig. 4.—*Serpentine adhering to a ‘step’ of granulite, in Polbarrow Cove.*



case from the same cove (fig. 5), where the junction-surface is irregular, the granulite for a short distance is disturbed, and two or three small fragments of it occur in the serpentine. Or this one from Enys Head,

Fig. 5.—*Banded granulite (with fragments in serpentine), south of Poltesco Cove.*



where the serpentine seems to have forced open the granulite along the lines of banding, rumpling those in its immediate neighbourhood (fig. 6, p. 30). Or this other one from the same locality, where the junction-surface is puckered and squeezed up, while in one case (as shown in fig. 7, p. 30) the bands of the granulite are cut off by the serpentine. We found another, and a very marked instance of the same kind,

<sup>1</sup> I do not forget the case in Forfarshire described by Sir Charles Lyell, but I have not been in that part of Scotland.

<sup>2</sup> I may add that in districts where the rocks have undergone much mechanical disturbance, the junctions, as a rule, are spoiled. Serpentine is a brittle rock, and commonly yields to strains before its neighbours, so that a line of junction is generally a line of fracture, and often of complete ‘smash.’ This rule is almost universal in the Alps.

near the White Rock, a little above sea-level, and the projection with bent bands (fig. 8) occurred, like those above, in Polbarrow Cove.<sup>1</sup> I have, indeed, sketches and notes of not a few similar cases in my journal, but forbear to multiply like figures and statements. I must, however, once more refer<sup>2</sup> to the remarkable mass in the quarry at Kildown Point, which again has been most carefully studied. Before the excavation was made, it must have been wholly or almost wholly enclosed in the serpentine. That rock still rests in places on the top; it forms one or two small tongues between the bands of granulite, and a blunt lobe at the base of the southern side, where some of these bands are bent and intercepted. Yet in the immediate neighbourhood of this mass the serpentine does not show the slightest sign of crushing; it is in a perfectly normal condition, while that in the lobe, though rotten, exhibits a slightly streaked or foliated structure, which, however, makes a high angle with the horizon, though the bands in the granulite are inclined at a low angle to the same. But this is not all the evidence. Masses of granulite appear to crop out from the serpentine on the almost precipitous slope below the quarry. The descent of this would be so hazardous that I have never made the attempt; but this year I managed to land from a boat in a little cove at the base of the cliff. Here we find granulite

Fig. 6.—*Serpentine and banded granulite, Enys Head.*

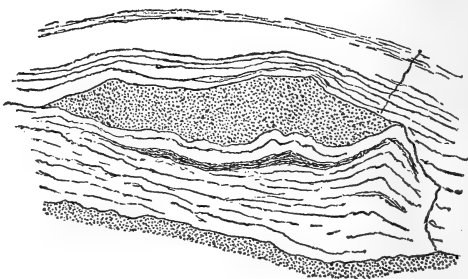


Fig. 7.—*Serpentine and banded granulite, Enys Head.*

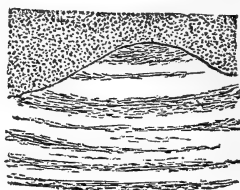
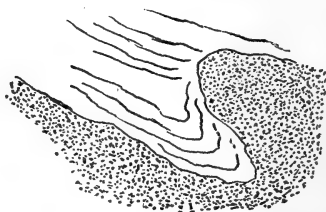


Fig. 8.—*Serpentine and banded granulite, Polbarrow Cove.*



<sup>1</sup> Compare also the projecting mass of granulite in the included mass east of the Lion Rock (fig. 3, p. 27), and note the outlines of the granulitic part and of the micaceous bands.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 469; see also vol. xxxiii. (1877) p. 899.

forming the southern, and serpentine the northern side of the cove, and in the middle part a mass of granulite through which in more than one place serpentine 'breaks irregularly, exactly as it would break through a rather hard sedimentary rock, in places forcing back and crumpling up some of the bands.'<sup>1</sup> One mass of serpentine, of which I made rough sketches, was about 4 yards long and 2 wide. That also showed a slight foliation or fluxional structure, and this too was nearly at right angles to the bands in the granulite. All the way up the crags above this place we see outcrops both of the one rock and of the other.

I submit then, that these instances (and it would be easy to go on multiplying them) show that the serpentine is really intrusive in the 'granulite.' The former rock, however, must have been at this time only in a semi-fluid condition—viscid and tough—so that it was not able to do more than force its way occasionally along planes of weakness in the 'granulite' (blocks of which it often included and perhaps tore away), softening the latter rock locally and squeezing it about, though the effect which it produced generally extended only for a few inches away from the actual junction-surface.

### (b) Relations of the Serpentine to the Hornblende-schists.

The best sections for studying these relations, so far as I know, are at 'Potstone Point,' on the cliffs north of Ogo-dour, and at Henscath, on the west coast; at Carnbarrow and in Porthallow Cove on the east. Except the first, these were well known to me, and of it I had a general knowledge. All, however, have been carefully examined. First, with regard to the Potstone Point sections, of which Messrs. Fox and Teall have given so admirable an account.<sup>2</sup> These lead, in their opinion, to sundry conclusions, of which I quote three,<sup>3</sup> as the rest need no further discussion:—

'(1) The hornblende-schist and serpentine of the Ogo-dour district form together a banded complex of crystalline foliated rocks.

'(2) The relative ages of hornblende-schist and serpentine cannot be satisfactorily determined, but the occurrence of lenticles of serpentine in hornblende-schist points to the conclusion that, if there be any difference in age, the serpentine is the earlier.

'(3) The complex of schist and serpentine has been folded after the banding was produced, and before the dykes were intruded. Some, if not all, of this folding probably took place when the complex was formed.'

Of these the second and third alone are important, because without them the first, so far as I understand the word 'complex,' commits us to very little.

In this locality also the question between us is one of interpretation rather than of facts. I gladly avail myself of the opportunity

<sup>1</sup> Quoted from notes written on the spot.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 200.

<sup>3</sup> *Ibid.* p. 210.

of expressing my admiration of the map published in Messrs. Fox and Teall's paper.<sup>1</sup> The making of it must have been no easy task, for the slope is very irregular, broken, and sometimes not the place for an unpractised climber. So accurate are both it and their description that I had no difficulty in following them step by step in going over the ground. This, then, is how I interpret the sections.

Nowhere in the serpentine can I find any of those symptoms, so familiar to me, which indicate that after solidification it has been subjected to severe mechanical disturbances (dynamo-metamorphism. The two cases, figured by my friends<sup>2</sup> (and the number of such is small), appeared to me due to a different cause. The intrusion of a hot viscid mass into one already solid suffices sometimes to bend either the latter locally or pieces of it which have been torn off.<sup>3</sup> Here there is no sign of the two rocks being folded as solids.

Furthermore, here and there, the serpentine includes slabs of hornblende-schist of normal aspect, or the junction of the two rocks may be often seen (as will be presently described), to be perfectly welded and yet distinct. In one case (fig. 9) the serpentine runs up to the broken edges of a wedge-like projection of the hornblende-schist. In the latter rock the banding is regular, only a little rumpling and flexure being perceptible at two places, which are respectively 2 feet and 4 feet in a line from the point of the former rock, while the mass as a whole is not affected. The disturbance, in short, reminds one of the crumpling which might be produced by thrusting the thicker end of a flat paper-knife between the pages of a tightly-closed book. The serpentine in parts of this 'complex' appears to be sometimes impure and harder than it ought to be; often it is streaked like a brownish slag, while here and there a thin band can be discovered, which resembles hornblende-

Fig. 9.—*Banded hornblende-schist in serpentine, Potstone Point.*



The dotted rock represents serpentine, the lines indicate diagrammatically the banding of the hornblende-schist.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 203 (I had it with me as I worked). Once or twice I felt doubtful about the small faults, and should have made a slight change as to a dyke; but these are insignificant details, and I, not they, may be wrong.

<sup>2</sup> *Op. cit.* p. 212.  
<sup>3</sup> Which explains figs. 1 and 2, *op. cit.* p. 202. Under these circumstances the junction-surface of the two rocks might be 'wavy,' and 'for every tongue of serpentine into schist [there would be] . . . a corresponding tongue of schist into serpentine.' In such cases also the two rocks would probably exhibit a parallel foliation. This does not appear to have occurred to my friends, and I find no evidence that they minutely investigated the structure of the serpentine, in which, however, the key of the position is to be found.



schist, and seems to pass rapidly into the adjoining serpentine.<sup>1</sup> In the field I came to the conclusion that the latter rock had intruded into the former, occasionally breaking off pieces of it and even locally melting them, wholly or in part. Let us then see how far this conclusion is supported by study with the microscope. Taking first a slice cut from a specimen which showed (as I supposed) a junction of the serpentine and hornblende-schist, I find that the greater part consists of a serpentine (mineral) of a brownish or greenish-orange colour, exhibiting a structure which, if this were an acid rock, I should not hesitate to claim as fluxional. In this groundmass are scattered clear grains of a mineral without definite external form or any well-marked cleavage, which, however, I think may be identified as a hornblende, together with one crystal of a serpentinized bastite, including rods of a monoclinic pyroxene. Besides these are numerous granules, often aggregated, of a fairly translucent brown mineral; some, doubtless, are picotite, but others, which exhibit double refraction, are probably hæmatite. This part is succeeded by a streak rich in pyroxenic grains, many of them light brown in colour; and the latter rock (sometimes after an intervening film of the former one) changes to a band (slightly irregular in outline) consisting of felspar, in a very decomposed condition,<sup>2</sup> of hornblende, warm brown in colour, and of a moderate number of grains, which probably are a white augite, though the mineral is rather 'dirty' and sometimes serpentinized. This band is about  $\frac{1}{5}$  inch wide, and the slice then is ended by a serpentine like that already described. But on examining the hand-specimen, this serpentine appears to be little more than a film, for in not more than one-fifth of an inch we find fairly normal hornblende-schist. Next let us take two specimens from a part of my friends' section<sup>3</sup> near the porphyritic dyke. It is thus described in my notes:—'A curiously banded and streaked rock, exhibiting fine compact bands and coarser-looking brown bands, in parts much wrinkled and once or twice slightly brecciated, somewhat resembling serpentine, but rather harder than is usual with that rock. I have a strong suspicion that this is a mixture of serpentine and hornblende-schist, the latter being partly melted down by and carried along with the former.' Of one specimen, cut where the streaky structure is much curved, one would claim part, without hesitation, for hornblende-schist. It exhibits (Pl. I. fig. 5) the usual rather granular structure, and consists mainly of a felspar, somewhat decomposed, and hornblende, which, however, is brown instead of the ordinary strong green colour. In other parts (streaks) we find the grains of brown hornblende in a 'matrix' of composite microgranular

<sup>1</sup> I suppose, of course, that the serpentine was a peridotite at the time of the intrusion. This must be understood throughout.

<sup>2</sup> It is whitish by reflected light, earthy brown by transmitted, and shows specks of brightest colour with crossed nicols.

<sup>3</sup> *Op. cit.* p. 203 (map). I think it is from the part *S* and *Sch* below the patch marked *e*. Whether this be the top of a 'dome' or not, I believe it to be an included mass, or, at any rate, to indicate intrusion on the part of the serpentine.

minerals; in others this 'matrix' is the orange-coloured serpentine already mentioned. Other streaks consist of this serpentine with rather small pyroxenic grains. All these varieties are associated in a slag-like fashion (Pl. I. fig. 6). A slice from another specimen, rather more serpentinous in aspect, exhibits a junction of two kinds of rock. One presents the general structure of a hornblende-schist, but the grains of that mineral are brown, while the others, instead of being felspar, are commonly a brownish-orange or greenish serpentinous mineral, which in some cases, when examined with crossed nicols, resembles a bastite, in others prove to be a granular aggregate. The other kind of rock exhibits a very marked fluxional structure in a matrix (if one may so call it) which seems to be composed of minute doubly-refracting minerals, and its bands are darkest when parallel with the vibration-planes of the crossed nicols. This is spotted with a brown hornblende, which occurs both in granules and in grains of the usual size, and the above-named structure is almost at right angles to a very slight parallel ordering of the grains in the other part (Pl. I. figs. 3 and 4).

This, however, is not all. Let us examine a piece of hornblende-schist which was included in the porphyritic dyke.<sup>1</sup> It is a fairly well-banded variety, thoroughly typical, except that it is a little duller or of a more 'greasy' aspect than is usual.<sup>2</sup> Under the microscope we find a rather marked difference between the bands. Those which are lighter coloured in the hand-specimen, and are spotted with white in reflected light, consist of a very decomposed felspathic mineral, and of pyroxenic minerals, some (the less numerous) brown hornblende, others a pale green rather fibrous hornblende, and yet others consisting of aggregates of minute minerals. In certain bands the brown hornblende dominates, and some felspar still remains, while in yet another band the granular structure has wholly disappeared, and the rock consists of numerous colourless flakes or prisms (about .02 inch long), which have the extinction of actinolite, and are set in a mass of smaller flakes, probably, in part at least, a white chlorite. Here then a specimen of hornblende-schist, once normal, which has been affected by 'contact-metamorphism,' unites the characteristics to which I have just called attention and those mentioned in our last paper,<sup>3</sup> as belonging to supposed

<sup>1</sup> A specimen of this dyke, taken from close to the included hornblende-schist, has been examined with the microscope. In one part of the slide there are indications of mechanical disturbance. This, however, is almost certainly due to some accidental cause, such as a slight faulting, which escaped notice in the field; for the porphyritic felspars are uninjured, and the other parts exhibit a hypophitic structure. The felspar is generally decomposed, and the augite has been replaced by a dirty-looking secondary product, which shows a composite structure with crossed nicols. The rock is readily distinguishable from the hornblende-schist.

<sup>2</sup> Its specific gravity is 2.917, that of a speckled variety from S. of Kileobben Cove 2.986, that of a banded (epidotic) variety from Church Cove 3.074. The specific gravity of the serpentine in this district is 2.730 (pit between Mullion and Lower Predannack) and 2.766. The specific gravity of two of the specimens of the streaky rock described above is 2.935 and 2.954. This is significant.

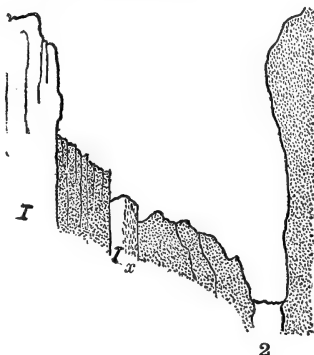
<sup>3</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) pp. 472-73.

cases of contact-metamorphism produced in hornblende-schist by serpentine.

But before quitting this subject I must again refer to the locality near Parc Bean Cove, north of Ogo-dour,<sup>1</sup> where I have already asserted the serpentine to exhibit true intrusive junctions. Again, perhaps for the fifth time, I studied this rocky slope with scrupulous care. Here the serpentine has forced itself in a rather irregular fashion through hornblende-schist, though it conforms on the whole to the banded structure in the latter rock, slabs of which appear occasionally to be broken off by and caught up in the serpentine.<sup>2</sup> In this part the serpentine, which is sometimes streaked, and in which the bands occasionally present some resemblance to hornblende-schist, is very rotten, but at a short distance the rock is in better condition. A few yards to the west of this complicated area,<sup>3</sup> a gully exhibits the junction of the principal masses of serpentine and of hornblende-schist. Here, as shown in the annexed figure (10), a slab of hornblende-schist is separated from the main mass by a 'sill' of serpentine. This slab, where it was drawn, was about  $3\frac{1}{2}$  inches thick, and it tapers away in a yard or so to less than  $1\frac{1}{2}$  inch. That the hornblende-schist about here is the ordinary rock cannot be doubted; it exhibits both the 'dioritic' and the 'banded' varieties. The serpentine, generally more or less decomposed, is a little 'platy' in the direction of and parallel with the junction-surfaces, but this structure is in no way suggestive of crushing. The serpentine also is occasionally harder than is usual and looks impure. It is locally streaked, alternately warm brown and brown-black in colour. When the included hornblende-schist becomes very thin—say not more than an inch in thickness,—it is sometimes difficult to fix upon the exact line of junction, but where it is thicker, this is generally sharply defined, and the weld between the two rocks is perfect.

I have examined a specimen of this streaky serpentine (obtained from near a weld) under the microscope (Pl. I. fig. 1). The darker

Fig. 10.—*Gully north of Ogo-dour. Intercalation of serpentine and hornblende-schist.*



- I = Hornblende-schist (more or less banded, as at x).  
 2 = Bottom of gully.  
 Serpentine dotted.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 22, and vol. xlvii. (1891) p. 470 (with General McMahon).

<sup>2</sup> The bands occasionally are cut across by the serpentine.

<sup>3</sup> It could only be accurately mapped on a very large scale-map, and the trouble of doing it would not be repaid by the result.

bands consist of a very pale green serpentine thickly speckled with opacite or streaked with clusters of the same substance; the lighter of the orange-coloured serpentinous mineral, mentioned above, of a colourless, but rather 'dirty' pyroxene,<sup>1</sup> and of barely translucent brown granules, in part at least iron oxides, more or less hydrous. In short, this rock in parts closely resembles the serpentinous portions of the Potstone Point specimen.<sup>2</sup> I have also examined a specimen of the hornblende-schist in contact with the serpentine. The fragment—from the face of the mass on the left hand of the figure—is about an inch thick. Beginning with the part farthest from the other rock, we find a band from  $\frac{1}{4}$  to  $\frac{1}{3}$  inch broad, which exhibits a granular structure like that of an ordinary hornblende-schist, the hornblende being roundish in outline and brown in colour, and the other grains composed of an 'earthy' material, no doubt replacing felspar, which, indeed, here and there can be recognized. A thin lighter-coloured band succeeds, still containing grains of brown hornblende, but with a more fibrous structure in the intervening material. This is followed by a generally similar layer, in which, however, the hornblende-grains are paler in colour, though, with the polarizer, they exhibit a brown pleochroism. In the remaining part of the slide (about  $\frac{1}{3}$  inch) the brown colour of the hornblende-grains is less conspicuous, and they are sometimes embedded in a pale-green fibrous mineral. The interval, in short, between the grains everywhere appears to be a variable mixture of minute minerals, of a more or less fibrous habit, among which I think actinolite and serpentine may be recognized, and near the very edge, where the grains of hornblende become less frequent, are dull orange-coloured patches, perhaps only staining, and the rock becomes more definitely fibrous. Granules of iron oxide, as might be expected, occur here and there in the slice.

Another specimen, from a part of the adjacent hillside, where the serpentine appears to have forced its way between two slabs of hornblende-schist and to include a little streak of the latter, is very interesting. This streak is about an inch thick, and the slice has been cut through it (Pl. I. fig. 2). Beginning on one side we find a greenish, orange-coloured serpentinous mineral, in which are scattered more or less acicular microliths of a colourless hornblende. As these microliths increase in number, the former mineral is replaced by a more or less distinctly fibrous one, though the transition between the two kinds of rock is rather abrupt, as in the case of fluxional streaking; then comes a brownish hornblende, rather more granular in habit, associated with a colourless mica-like mineral, probably a chlorite. Lastly, the hornblende-grains, still generally composite in structure, but becoming larger and more definite, are parted by earthy spots like the residue of felspar, and from this

<sup>1</sup> Probably white hornblende, for the mineral occurs in all the serpentine of this neighbourhood.

<sup>2</sup> The specific gravity is 2.539, that of the Predannack serpentine, as already stated, being 2.766, but the difference is probably due to decomposition.

condition, as we approach the other edge of the slice, we pass back, speaking in general terms, through the conditions already described.

I have again examined the sections at Henscath, Carnbarrow, and in Porthallow Cove. As regards the first and second, I could fill a page with minute descriptions, but may content myself with saying that I found it impossible to explain what I saw, either by displacements due to earth-movements, or by the flowing together of differentiated magmas, or by anything else than the intrusive action of the serpentine on the hornblende-schist, after the latter had become solid. As for the Porthallow sections, it may suffice (except in regard to one interesting detail) to refer to what has been already published, and to copy the words which I wrote on the last occasion in my journal:—"Some of the cases here are inexplicable to me on any hypothesis other than that of an intrusion of the serpentine into the schist. It may be said that 'the two have flowed together,' but the serpentine sometimes cuts across the edges of bands in the other rock in a way which suggests direct fracture and not the result of a strain-slip. The serpentine may indeed sometimes bend with the bands, but that proves no more than that the schist (like the included fragments of gabbro near Manacle Point) has been somewhat softened and made flexible. The bending cannot be attributed to subsequent earth-movements, because the serpentine does not show the slightest sign of crushing, and the weld between the two rocks is often perfect."

But an examination of the specimens collected on this occasion has enabled me, as the result of the whole work, to clear up a difficulty which this Porthallow serpentine hitherto had presented. We find here and therein it, close to junctions with the hornblende-schist, grey bands, which are intermediate in aspect and hardness. Is this a less pure variety of serpentine, a streak of picrite, which, as indicated by the analysis, is present in the rock? and, if so, how can we explain its presence?<sup>1</sup> I had hitherto vaguely referred it to some differentiation in the magma, but can now offer a more precise explanation, in accordance with the cases already described. I brought away a few specimens for further investigation. One of these, about  $4\frac{1}{2}$  inches long, consists mostly of the ordinary Porthallow serpentine (a little redder in colour than usual); the remainder, a band about an inch thick, is of a greenish-grey colour, and this was in contact with, though here not welded to, a dark-grey, minutely speckled rock, which in hardness and general aspect agreed with a hornblende-schist. The latter, on examination with the microscope, exhibits traces of a banded structure; in some bands are residual grains of felspar, and with them grains of brown hornblende, but the greater part of the rock consists of flakes or longish prisms of actinolite in a felted mass of the same or of a colourless chlorite. The red part of the other specimen is a fairly normal serpentine (Porthallow type). It consists chiefly of the peculiar orange-coloured granular serpentine (mineral), often much stained with hæmatite, the latter also occurring in minute rods,

<sup>1</sup> See paper by Gen. M<sup>c</sup>Mahon and myself, *op. cit.* pp. 471-475, and table of analyses (facing p. 466).

and of small elongated prisms of colourless hornblende. It contains, however, a number of small 'inclusions,' consisting almost wholly of clustered ferrite, surrounded by a clear zone, not quite so broad as they, of actinolite; and two larger inclusions (?), much ferrite-stained, recall the structure of a fluxion-breccia. This part of the slice is separated from the grey band by a rather sharply defined border. The latter affords indications of a banded structure in the presence of ill-defined lines of brown hornblende-grains (not numerous), of felspar(?) grains, and (chiefly) of a felted mass of flaky or acicular actinolite, with which probably a colourless chlorite is also associated. These specimens, with that from Parc Bean Cove described above, lead me to the conclusion that their adjacent faces indicate the junction-surface of the two rocks, but that here also the outer part of the serpentine has been rendered impure by some superficial melting of the hornblende-schist.<sup>1</sup>

The facts cited above, it may be worth while to repeat, seem to indicate that the brownness of the hornblende<sup>2</sup> is one indication of contact-metamorphism, while a more extreme result of the latter is the production of a rather fibrous, somewhat minute actinolitic hornblende and of sundry flaky minerals (representing the aluminous constituents of the rock), probably light-coloured chlorite or mica.

Here I may refer to a section which has been mentioned more than once in former papers,<sup>3</sup> namely, that exhibited in a low crag at the foot of the main cliffs, north of Kynance Cove. On each visit I have spent some time in studying it, without, however, feeling much more certain as to its exact interpretation. As described on the first occasion, serpentine occurs on either side, and in the cliff above, the craglet in question, which exhibits, apparently in vertical bands, "(2) a mass of grey, rather sandy, 'hornblende-schist,' about 8 feet thick, with apparently many thin laminae of red serpentine; (3) red serpentine, rather fissile in structure, 2½ feet; (4) a dark brownish-grey rock with crystals rather resembling diallage, 2 feet; (5) red serpentine, 4½ feet, divided by a thin [rather wedge-shaped] band of the schist, then bedded schist like (2), with the apparent layers of serpentine, for about 6 feet."<sup>4</sup>

<sup>1</sup> It may be well to remark that the serpentine of the Lizard is generally very uniform in structure, and only departs from this rule (and that by no means always) in the immediate neighbourhood of a junction with hornblende-schist.

<sup>2</sup> I have more than once called attention to the fact that in hornblende a brown colour often precedes the green; the latter may indicate an early stage in the process of hydration, affecting the ultra-microscopic grains of iron oxide or some constituent to which the colour is due.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xxxiii. (1877) pp. 888, 920; vol. xxxix. (1883) p. 23.

<sup>4</sup> 'Rather more than 7 feet' was my note in 1894; the measurements then were a little more precise than on former occasions, but the differences are so slight that I leave the passage as it stands. Between the last-named 'schist' and the serpentine (5) is a thin darkish dyke, which I had supposed to be part of the schist, and there may be another in the latter.

Afterwards I described the microscopic structure of the rocks, pointing out that the serpentine is an unusually compact variety, and stating that I regarded the mass as representing a block of hornblende-schist, caught up by the serpentine, altered thereby, and probably since then further changed by the action of water. In the 18 years which have elapsed since I wrote these descriptions, my experience has been considerably enlarged, yet I still find the rock numbered (4) a very perplexing affair. I note that it is sporadically porphyritic, that the larger crystals under the microscope appear to exhibit traces of 'lustre-mottling,' that the wedge-shaped piece included in the serpentine (5) is almost certainly a more compact variety of the same rock, and that this may have been a picrite; also that the serpentine is probably the intruder. But I can now throw a little light on the banded structures, which are among the perplexities of the section. On examining the dyke-like serpentine (3) I found that towards the edges it gradually became banded. This structure on the right-hand side began to be indicated about 2 inches from the exterior, but only became very marked in the outer inch, where a grey tint predominated. The red part, on microscopic examination, is found to owe its colour to hæmatite-staining, and to consist of a serpentine (mineral) thickly crowded with minute flakes of a clear mineral, many of which give oblique extinction, and resemble actinolite, but others give straight extinction, being probably a chlorite. The last inch, however, is practically colourless (only spotted with a few grains of iron oxide), consisting of matted flakes, quite double the length of those in the other part, but the same minerals. The edge of the serpentine (5), where it is in contact with the small dyke, exhibits a band about  $\frac{1}{4}$  inch wide. The red part resembles that described above, except that it seems to be a rather purer serpentine, and it contains one or two ill-preserved grains of bastite, while the band itself consists of a streak of fairly clear orange-coloured serpentine, followed by the matted minerals just mentioned, in which a kind of bandlet is formed by some small grains of brown hornblende, with a little streaking of serpentine. I have also examined a piece of the dyke, which is in contact with this face of the serpentine. Probably it was once a basalt; it has consisted mainly of two minerals, each of which has been replaced by secondary microliths: the clearer patches probably representing a feldspar, the others almost certainly a pyroxene. But attached to this is a zone, which in the field I thought might represent a junction. This bears a considerable resemblance to part of the border in the other specimen, for it consists of a matted mass of acicular minerals, some being considerably larger than the rest and distinctly actinolitic, in which one or two grains suggest the possibility of having been bastite. Besides these I have examined a piece of the striped red-and-grey rock (the supposed schist) in the left-hand part of the crag, where the bands locally are sharply folded. The red rock is a serpentine, like that already described; the grey one is a mass of microliths, generally too minute for iden-

tification, but here and there in it are zones of larger flakes, in part at least actinolitic, spotted with grains of hæmatite and of a pyroxene, in some cases certainly hornblende.

Whether the whole of these two masses, which I formerly supposed to be mainly altered and decomposing hornblende-schists, consists of serpentine streaked with bands, which are more nearly picrites in composition, it would be impossible to say without another and yet more minute examination, and this, perhaps, after all would hardly repay one for the trouble; for it is now clear that this section affords a conspicuous instance of a banding in the serpentine itself. As to the two larger, apparently included, masses of 'brownish-grey' rock, I incline to regard them as pieces of a picrite, rather than as exceptionally altered fragments of the hornblende-schist, but in the present state of my knowledge cannot venture to speak more positively.

### V. CONCLUSIONS.

I submit, then, that the facts described in this paper justify the following conclusions:—

(a) Mechanical forces, due to earth-movements, have only rather locally produced important effects on the crystalline rocks of the Lizard: namely, in a very limited area at Porthallow, near the great boundary-fault, and over a larger one in the south, approximately bounded by a line drawn from a little east of Polpeor to rather south of Caerthillian Cove.<sup>1</sup>

(b) Elsewhere the results of such forces are of very secondary importance, being restricted to the neighbourhood of faults, and even there producing commonly very limited effects.

(c) The slightly foliated or linear structure rather common in the serpentine, its occasional distinct banding, together with rather similar structures in the gabbro and a faint approach to them in certain basic dykes, as has been more fully shown in the paper by General M<sup>c</sup>Mahon and myself, have nothing to do with 'dynamo-metamorphism,' but have been produced by fluxion-movements anterior to the complete consolidation of the rock.

(d) The serpentine is intrusive in the 'granulitic group,' which, however (though it may have torn off large blocks), it has only locally softened and indented. It is also intrusive in the hornblende-schist, but this it has sometimes riven, and occasionally melted down, in certain cases partially, in others perhaps wholly, thus producing the streaks of a less pure character, with some resemblance to the former rock: these phenomena, as might be expected, being restricted to the exterior of the mass, the rest of it generally exhibiting an uniform character for considerable distances.

In short, though the effect of twelve years' work in the field and with the microscope has caused me to change my views as to the

<sup>1</sup> An area very nearly correspondent with that assigned to the 'mica-slate series' of Sir H. De la Beche. The line, if it runs straight (I have not attempted to trace it), would be roughly from N.W. to S.E.



genesis of the 'granulitic group' and the hornblende-schists, I adhere (except in regard to a few matters of detail) to the conclusions which were expressed in my paper published in 1877, and more emphatically than ever to those expressed in the first three of the above paragraphs—namely, that I can find no ground for attributing the foliated or banded structures, whether in the granulitic and the hornblendic groups or in the serpentine, gabbro, and a few basic dykes, to dynamo-metamorphism. As regards the banding of the granulitic and hornblendic rocks, I can only say that if it be due to any kind of shearing in solid heterogeneous materials—it is not easy to follow mentally the steps of the process—recrystallization has been so complete that the usual indications of such action have vanished. Hence the structure must have been produced anterior to the incoming of the serpentine and the gabbro. Yet, if the serpentine were folded together with the granulitic rock so as to distort its bands, traces of crushing and shearing should be found in the latter. Even if we assume these to have disappeared (which I could not admit) and claim the foliated and banded structure occasionally exhibited by the gabbro as a result of dynamo-metamorphism, what is the testimony of the serpentine? It is sometimes welded to the granulite, often to the hornblende-schist; it is constantly cut intrusively (everybody, I believe, grants this) by dykes or veins of gabbro. But the serpentine almost invariably shows no signs of crushing. Strain and pressure might destroy a weld, but I never knew them produce one between rocks of this kind; hence the foliation and banding of the serpentine cannot be due to any such cause.<sup>1</sup>

But serpentine is a much more brittle rock than granite, hornblende-schist, or gabbro; the last, as one quickly learns in the Alps, being a very obdurate material. Hence earth-movements, which would affect these rocks, would leave their marks distinctly enough on the serpentine. This is a brief summary of my observations in regard to it. Under strain, perhaps under moderate pressure, serpentine simply brecciates<sup>2</sup>; when the pressure becomes more severe the rock breaks into pieces, which are generally rather lenticular in shape, with a 'glaze' on the outside,<sup>3</sup> and, as a final stage of the 'peine forte et dure,' the serpentine becomes so slaty that it might be sometimes used for roofing purposes.<sup>4</sup> The Alps afford many

<sup>1</sup> On this point I am not afraid of being accused of speaking dogmatically. My first visit to the Lizard was in the autumn of 1873, and I speedily fell a victim to the fascinations of serpentine, probably because I found it to be a subject where *quot homines tot sententiæ* held good. I have never felt strongly attracted to beaten paths. Since then I have studied serpentine (including peridotite) in the field on an average once in a year. I have returned five times to the Lizard, I have been thrice to Anglesey, I have examined the rock in three districts in Scotland, in at least a dozen separate localities in the Alps (in some cases not only as a passing traveller), in two districts of the Apennines, and in the Pyrenees, besides studying with the microscope specimens collected expressly by myself, with many others acquired by gift or by purchase. The effects of earth-movements also are not novel to me, since for more than a dozen years I have been studying these in the Alps and elsewhere.

<sup>2</sup> Geol. Mag. 1879, p. 365.

<sup>3</sup> *Ibid.* 1880, p. 538, and elsewhere.

<sup>4</sup> *Ibid.* 1890, p. 533.

opportunities of studying these changes. Towards the outside of a large mass, in a region which has undergone severe pressure, one may find the 'lenticular' structure, and it is vain to hope for a decent specimen, but as we pass inward the rock often becomes less brecciated, so that at last fairly normal specimens may be obtained. Even the slaty structure may not affect the whole of a large mass; now and again portions of it escape comparatively uninjured. Of this, however, we may be sure, that if a force had acted sufficient to produce a marked effect on either the granulite, the hornblende-schist, or the gabbro, the serpentine would have been almost invariably torn apart from the weld, and would have been crushed, perhaps to a slate, for at least a considerable distance from the junction.<sup>1</sup> If, then, the relations of the serpentine with the granulites and the hornblende-schists indicate an 'igneous complex,' if its structures and those of the gabbro are the results of dynamo-metamorphic action on the rocks when they were solid, the Lizard district flatly contradicts everything which I have learnt about rock-structures during more than twenty years of work in the field and of studying under the microscope specimens collected with my own hands.

## VI. APPENDIX.

### (a) Miscellaneous Notes.

It would be a very long task to examine every rock in such a district as the Lizard, so that even in going over ground comparatively familiar one picks up 'crumbs' of information, some of which may be worth a brief record.

*Dykes.*—A porphyritic diabase, as described by Messrs. Fox and Teall, and by Gen. McMahon and myself, is occasionally found, usually in rather thin dykes. Those hitherto recorded, if not actually confined to the hornblende-schist, are closely associated with it, as near Potstone Point,<sup>2</sup> but we came upon one cutting through serpentine (the variety with small crystals of colourless hornblende) near the path<sup>3</sup> leading from Mullion Village to Predannack Wartha. The hornblende-schist, near the western end of the cliffs on the northern side of Porthoustock Cove, is cut obliquely by a yellowish rock, generally rather decomposed, which, though only a few inches thick, is more like a dyke than an infiltration-vein. I find this on microscopic examination to exhibit a finely granular structure not resembling any of those usual in veins, and to consist of epidote. This mineral no doubt readily forms as a secondary product in rocks of suitable composition, but the uniformity in composition is a little strange. Such an epidosite would come most readily from a rock composed of a lime-felspar with some minutely

<sup>1</sup> The effects of pressure are never more conspicuous than in the weaker of two rocks near the junction-surface.

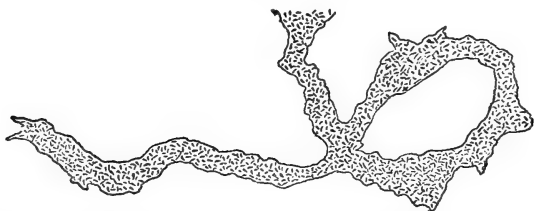
<sup>2</sup> P. 33.

<sup>3</sup> It is about 350 yards, in a line drawn rather N. of E., from Creggian Mill; in the same direction are two other shallow pits in serpentine.

disseminated iron oxide. Two or three dykes of coarse gabbro, very poor in the ferro-magnesian silicates, have indeed been observed on the coast farther south; can this epidosite have been a very compact variety of the same rock?

*Manacle Point and Porthoustock Cove.*—We can add a few notes to the description given by Gen. M<sup>c</sup>Mahon and myself.<sup>1</sup> The ordinary gabbro (which forms the Crousa Down *massif*) when followed along the shore towards Manacle Point, passes occasionally into a very coarse variety, in which the constituent crystals sometimes even exceed 2 inches in length. This forms patches in the ordinary rock, with ill-defined boundaries, suggestive of an imperfect mixture of heterogeneous materials in different stages of consolidation. Other parts of the gabbro are foliated, and these occur in like manner, so as to suggest local movements anterior to complete consolidation. The 'warm grey' or brownish rock intrusive in the gabbro,<sup>2</sup> especially as Manacle Point is approached, would repay a closer study than our arrangements allowed us to give it. It pierces and rips up the ordinary gabbro in a very curious fashion, and pieces of the latter sometimes assume singular shapes, as if they had been slightly softened and bent (fig. 11). Frequently, also, it

Fig. 11.—*Strip of moderately coarse gabbro included in granular dolerite (or gabbro), south of Porthoustock Point.*



The unmarked part indicates the latter rock. The sketch is diagrammatic. The inclusion represented measures nearly 2 feet from end to end.

includes flake-like fragments of the foliated variety.<sup>3</sup> Besides this, it rather often exhibits a porphyritic structure, the mineral being commonly felspar, but sometimes a variety of pyroxene, which forms green spots. The felspar-crystals are a dead-white colour, like that in the gabbro, ranging up to about half-an-inch in length. They are 'sporadic' in habit, occurring in small 'swarms,' sometimes more or less scattered. Sometimes, also, they are actually in contact, and it becomes difficult to distinguish them from the smaller rock-fragments. Occasionally a felspar, as it appears at first, proves on examination to contain a speck of diallage. In short, the

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 491.

<sup>2</sup> It is noticed on pp. 491 and 494 in the paper by Gen. M<sup>c</sup>Mahon and myself. As there stated, it is a kind of dolerite or fine-grained gabbro.

<sup>3</sup> The bearing of these observations on some of the reasoning in the earlier part of this paper will, I presume, be obvious.

intrusive finer-grained rock seems to have softened, bent or drawn out some fragments of the coarser gabbro, and even to have partly melted down others, destroying the pyroxenic rather than the feldspathic constituents, so that the latter are scattered sporadically in the newer rock.<sup>1</sup> Prof. Sollas, it will be remembered, has described a somewhat similar occurrence in the Carlingford district.<sup>2</sup> This intrusive rock is less abundant than the ordinary gabbro, but more so than the 'greenstone'<sup>3</sup> dykes, which cut them both, and usually do not exceed 4 or 5 feet in thickness.

A low spring tide enabled us to make a more complete examination of the southern side of Porthoustock Cove. As mentioned in our paper (p. 491), General M<sup>c</sup>Mahon and myself felt uncertain as to the nature of the rocks forming the shore and adjacent cliffs. They presented, as we remarked, some resemblance to the more dioritic members of the 'granulitic group,' and were cut by 'greenstone' dykes, like those mentioned above, the gabbro being near at hand; for we traced it on the slopes above the cliff almost to the head of the cove.<sup>4</sup> This time we managed to get along the shore eastward, to a point where the ordinary gabbro was exposed in the face of the cliff. Here the rocks on which we stood consisted beyond question of the fine-grained gabbro or dolerite, becoming, as usual, sporadically porphyritic in the neighbourhood of the coarser rock, and from this point we succeeded in following it westward, and convincing ourselves that, though somewhat disguised by the effects of faulting and weathering, it is the dominant rock on this side of the cove. It is cut, as has been said, by 'greenstone' dykes, and traversed not unfrequently by reddish veins. Some of these appeared due to infiltration, but others resembled a rather feldspathic gabbro, by no means identical with that forming the principal *massif*. Thus Porthoustock Cove marks the position of a fault or group of faults,<sup>5</sup> which brings together the Crousa Down gabbro, with its associated intrusives, and the hornblende-schist.

*Serpentine*.—We examined the mass at Porthkerris<sup>6</sup> more carefully than on former occasions. It is represented in the geological

<sup>1</sup> Microscopic examination confirms the statements made above, and discloses one or two other facts of general interest. In the granular ground-mass the feldspars are generally fairly well preserved; the pyroxenic constituent was originally an augite, very pale brown in thin sections, which now, without change of external form, is replaced by a brown, strongly pleochroic hornblende (brownish straw-colour to rich brown). The feldspar of the included fragments is almost wholly replaced by secondary and mostly earthy material; the augite by fibrous, often felted, aggregates of a greenish actinolitic hornblende. Here and there the included fragments are so minute that one can hardly identify them with certainty.

<sup>2</sup> Trans. Roy. Irish Acad. vol. xxx. (1894) p. 477. The changes, however, in this instance are different—probably owing to local circumstances—from those observed by him.

<sup>3</sup> I use this vague term designedly, for they may be anything from a fine-grained dolerite or basalt to a hornblendic diabase.

<sup>4</sup> Still cut by the fine-grained gabbro or dolerite and by the 'greenstone.'

<sup>5</sup> The coves in the Lizard almost invariably correspond with one or more dislocations.

<sup>6</sup> Polkerris in earlier papers. In this I have followed the nomenclature of the 6-inch Ordnance map.

map as coming down to the shore on the northern side of the cove; but if there be an outcrop here, it was concealed on this occasion. At any rate, I think it must be isolated from the main mass of the serpentine; this crops out in many places on the moorland which rises on the northern side of the little valley, being seen over an area measuring about 200 yards from east to west, and not more than this in a transverse direction, hornblende-schist cropping out south, east, and north of it. Whether this mass of serpentine is continuous with the one at Porthallow we could not determine, the two being separated by rather more than a furlong of covered ground. Macroscopically it agrees fairly well with one variety of that rock, but it is perhaps a little smoother in aspect and brighter in colour. It has been much cracked and then cemented by yellowish steatite, so that it is apt to break up under the hammer. The two rocks agree fairly well in microscopic structure, each resulting from the alteration of a fine-grained peridotite, which appears to have consisted simply of olivine and iron oxide (*i. e.* a kind of dunite).<sup>1</sup> We ascertained that at Porthallow the serpentine not only runs up the cliff in a dyke-like fashion, but also does this at each end, so that the shape of the mass might be compared—very roughly—to a flattish crescent with its back to the water.<sup>2</sup> The quarry afforded better sections than it had done for some years. I can understand doubts arising about the interpretation of particular sections, but not as to the general fact that the serpentine is intrusive in the hornblende-schist.

We again paid much attention to the structure in the serpentine resembling a foliation, which may be observed in many places, more distinctly on the western than on the eastern coast, though on the latter also, as from Kildown Point to Kennack Cove, it is often to be found. Frequently it is barely perceptible on a perfectly fresh face of the rock, becomes visible on wave-worn surfaces, and is quite distinct on weathered crags. It obviously proceeds from a slight alignment of the constituents in the original peridotite, and in the case of bastite-serpentine seems more especially determined by that mineral. While it is not seldom fairly persistent in orientation over considerable areas, marked changes in direction may be observed; and while in the neighbourhood of included masses of granulite it is sometimes parallel with the junction-surfaces, cases not unfrequently occur where it makes a high angle with them. In other words, we have failed to discover any necessary relation between the structures in the two rocks. The serpentines in which this 'foliation' exists do not exhibit, macroscopically or microscopically, any indications of strain or crushing, and I adhere to the opinion expressed by Gen. M<sup>c</sup>Mahon and myself,<sup>3</sup> that the structure was produced while the original peridotite was consolidating.

<sup>1</sup> I refer to the ordinary serpentine of Porthallow, regarding the banded variety as exceptional.

<sup>2</sup> The slopes here are steep, rough, and much overgrown with brambles and coarse herbage, so that it is not easy to map the outcrops, and we have not attempted to do this very precisely.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) pp. 447, 476.

We have already pointed out<sup>1</sup> that the Lizard affords two fairly distinct types of serpentine — one, that more generally known, containing distinct grains of bastite (*e. g.* Kennack Cove), and sometimes augite in addition (*e. g.* Coverack Cove); the other, in which the bastite, if present, is inconspicuous, while small crystals of white hornblende are abundant (*e. g.* south of Mullion Cove); the former being most abundant on the eastern, the latter on the western coast.<sup>2</sup> But we find the bastite-serpentine on the west coast to the south of Kynance Cove,<sup>3</sup> and again on the actual headland of the Rill. Here, also, within a short distance, the peculiar variety of serpentine occurs which has been said to contain felspar,<sup>4</sup> but I could not discover how they were related. From north of Kynance to Gue Graze the dominant serpentine is a rather compact, slightly streaked rock, which on the whole seems more nearly related to the hornblendic than to the bastite-serpentine. The hornblendic serpentine also occurs, though not abundantly, on the east coast; that at Porthallow<sup>5</sup> on the whole more nearly agrees with it than with the other; we find it on the shore for some little distance south of Poltesco Cove and from Cadgwith to Carnbarrow. But the most curious instance is at Kildown Point. In the quarry at the top we find the bastite-serpentine, while the mass at the foot of the cliff<sup>6</sup> is a very typical hornblende-serpentine. I regret that I have not from the first recorded the variety of serpentine in each quarry or outcrop examined; but, so far as I remember or have noticed, the serpentine, at places within a curved line drawn from Coverack to Kynance Cove, roughly symmetrical with the eastern coast, is generally the bastite variety, and that outside this line is the hornblendic variety, including with it the dull compact type already mentioned.

*Green Schists of the Southern Coast.*—We paid special attention to the relations of these schists with the normal hornblende-schists, and are more than ever satisfied that, as stated by Gen. M<sup>c</sup>Mahon and myself, they are only the latter rocks modified by extreme pressure.<sup>7</sup> In more than one place we were able to trace a gradual

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 23, and vol. xlvii. (1891) pp. 466–468.

<sup>2</sup> Sp. gr. (mean) of four specimens of the former (two determined for this paper) 2.62. Sp. gr. of three specimens of the latter (two determined for this paper) 2.755.

<sup>3</sup> As in the sections near the Lion Rock, described by Messrs. Fox and Teall.

<sup>4</sup> I remain sceptical as to the identification of this mineral with felspar, though I believe it to be an aluminous silicate.

<sup>5</sup> Its sp. gr. ranges from 2.545 to 2.644 (J. H. Collins); that of the Rill is heavier, 2.74; that of Gue Graze heaviest of all, 2.85 (M. W. Travers).

<sup>6</sup> See p. 30. The sp. gr. of a serpentine such as that at the top is 2.653, of that at the bottom is 2.698, which is very nearly that of the west coast serpentine.

<sup>7</sup> In regard to this my work in the Alps during the last few years has been very helpful; see Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 94, and vol. l. (1894) p. 279. [As this admission was quoted by a speaker in the debate to justify the extension of 'dynamo-metamorphism' to the whole region, I must point out that, by admitting a certain cause to have produced marked modifications in two very limited parts of a district, we, in effect, exclude it from the

change from the normal to the abnormal type. Still, the mass as a whole exhibits a little more variety in composition than is usual in the hornblende-schists. Gneissoid rocks occur in it, as near Old Lizard Head and on the south side of Holseer Cove, and masses of a brownish mica-schist at Polledan Cove (discovered by Mr. Fox), Polpeor Cove, and in the headland south of Holseer Cove. This last I had not before observed. It is seen, under the microscope, to consist of quartz and mica, mostly biotite, which, as in the similar rock in Polpeor Cove, has evidently suffered from pressure, and it contains grains, not very regular in shape, of a water-clear mineral, evidently of secondary origin. This may be felspar, but the refraction-index seems a little high for that mineral, and one or two grains show a slight pleochroism (reddish), so I think it more probably andalusite.

On the northern side also of Holseer Cove are two rather peculiar rocks. One is a slaty, purplish-coloured rock, which is found, on microscopic examination, to consist of grains of a clear mineral, much of which is isotropic (? opal) with a greenish mineral, extinguishing obliquely (probably a chlorite), ferrite, and opacite. The mode of occurrence in the field suggested the possibility of an intrusive origin, but I cannot say that the microscopic examination throws any light on this question. Nor does it help us with a purplish, slightly-streaked rock at the head of the Cove, which still more resembles an intrusive mass. It consists of grains of the above-named clear mineral, flakes of biotite, more or less altered, a little white mica, grains of iron oxide, and a few very small garnets. Both these rocks, whatever may have been their origin, are now schists, and with that group we must leave them.

### (b) Age of the Lizard Rocks.

Though I now think it more probable that the hornblendic as well as the granulitic groups are not altered sedimentaries, but peculiar forms of igneous rocks, I am more than ever convinced that they are older, perhaps very much older, than the serpentine and the other rocks intrusive in it—that is, I still consider them to be Archæan. It is needless to recapitulate arguments which have been more than once stated in print, but I may say that the resemblance of some of the gneissoid rocks of Sark and Brittany to those at the Lizard, and the practical identity of the hornblende-schists in the first and last localities, make it highly probable that they do not differ materially in age. Now, the gneissoid rocks of Brittany are older than the Cambrian, older even than the ‘Schistes de St. Lô’; while it is almost certain that the hornblende-

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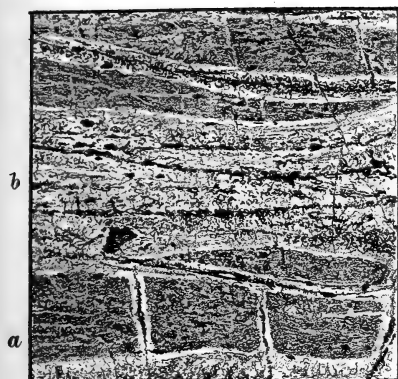
remainder. This, I may add, is not the only instance in which a like incorrect appeal has been made to the evidence of ‘dynamo-metamorphism’ at the northern and the southern boundary of the district.—January, 1896.]

schists of Sark, with many of the larger masses of crystalline rock in the Channel Islands, are pre-Cambrian, so that my estimate of the age of these rocks at the Lizard is not affected by any change of opinion as to their origin. But what is the age of the serpentine? It is older than the troctolite, the two varieties of gabbro, the granite, and the various 'greenstone' dykes. The last-named, indeed, may be very much younger than it; for some of them must have cooled quickly, and occasionally seem to be very fresh. Rather similar rocks, and the granite, elsewhere in Cornwall are certainly, at least in many cases, post-Carboniferous.<sup>1</sup> So possibly may be the 'dyke-rocks' at the Lizard. I think that the serpentine, the troctolite, and at any rate the coarse gabbro, must have followed one another rather quickly; the finer gabbro, however, which sometimes seems to become rather more compact near a junction, may be separated from the others by a longer interval, for reasons which I presume will be sufficiently obvious. But what is the date of the others? The picrite at Menheniot, which presents resemblances to some varieties of the Lizard serpentine, is intrusive in Devonian sedimentaries. This question, however, may be ultimately solved by a careful study of the rocks at the Nare Head between Gerran and Veryan Bays. I am indebted to Mr. Fox for my first sight of this most interesting district, of which, however, owing to unfavourable weather, I could only examine a very small part (at Pennare Wallas). Here, going southward up the slope of a hill, we found, first a slaty rock, then serpentine, then outcrops of gabbro. The serpentine, in which a shallow pit has been opened, is much crushed, so that it is difficult to obtain good specimens. It is, however, a dark bastite-serpentine,<sup>2</sup> very like that in Kildown and Kennack Coves, allowing for the effects of pressure. But on the northern side of this pit we find some of the sedimentary rock, which, though much crushed, is evidently a slaty mudstone with coarser bands, formed of materials which seem to have been derived from crystalline schists. The gabbro is identical with that of the Lizard, when the one constituent has become a kind of saussurite, and the other hornblende. The sedimentary rock is doubtless Palæozoic, although its exact age cannot be determined. The junction here very probably is a faulted one, but so far as I can learn, the crystalline schists do not appear in this district. Thus it looks as if the serpentine had broken through the Palæozoic sedimentaries. If this, on further examination, prove to be true, then it will be highly probable that the Lizard serpentine also is post-Archæan in age.

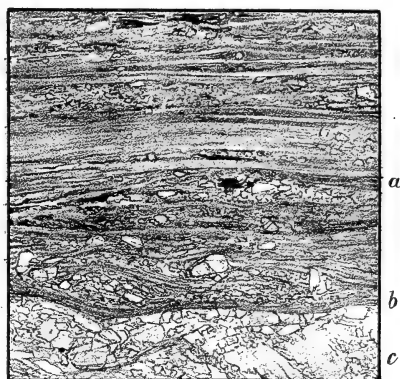
<sup>1</sup> Or at any rate later than any Carboniferous rocks in that region. But they are older than the rocks now generally regarded as Permian.

<sup>2</sup> Its specific gravity is 2.579; that of a specimen from the above-named locality is 2.647.

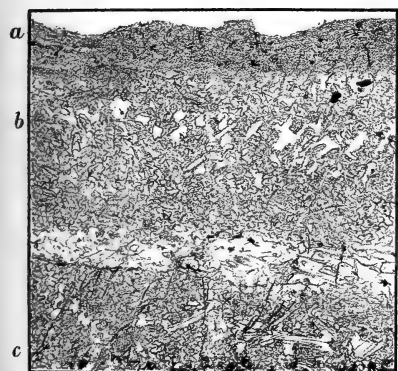




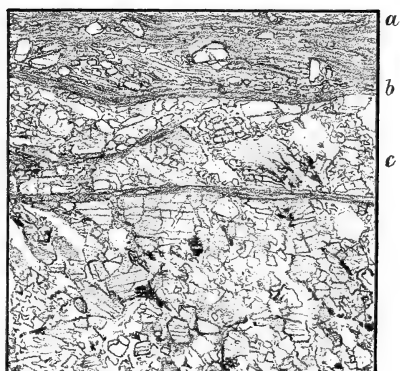
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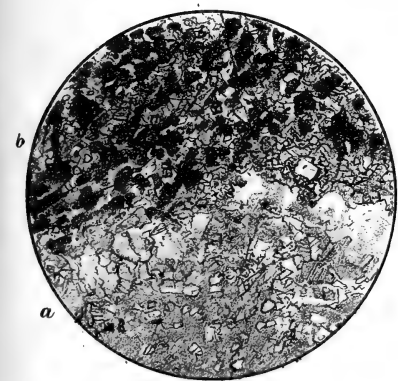
3. X 12



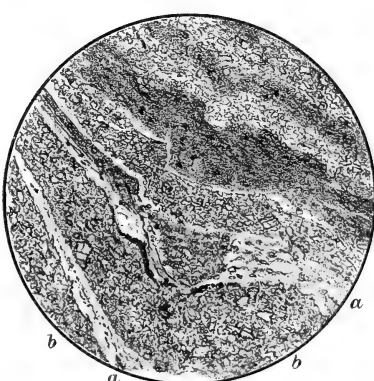
2. X 8.



4. X 12.



5. X 9.



6. X 9



## EXPLANATION OF PLATE I.

- Fig. 1. Intrusive serpentine, streaked brownish and blackish, from near Parc Bean Cove (see fig. 10 and description in text, p. 35). *a* is a band of the orange-coloured serpentinous mineral; the other bands (*b*) are lighter in colour, but often speckled with a light puce-brown and with opacite. The large dark grain is of a deep brown tint. ( $\times 8$ .)
2. From a band of serpentine, intrusive in hornblende-schist, and including a thin 'streak' of the same, from the section described near Parc Bean Cove (see description, p. 36). The part drawn represents the junction of the serpentine with the included streak of schist. *a*, film of true serpentine, forming outer part of specimen; *b*, fibrous minerals—brownish hornblende, chlorite (?), etc.; *c*, more granular brown hornblende, and dark 'earthy' spots (decomposed felspar). ( $\times 8$ .)
- 3, 4. Junction of serpentine and hornblende-schist near 'Potstone Point.' The two rocks, as described in the text, are 'fused' together. In order to represent this better, 4 is in part a repetition of 3, the lower portion of the former corresponding with the upper portion of the latter. *a* represents the serpentine with a fluxional structure. It contains grains of brown hornblende, which are more conspicuous near the junction *b*; *c* is hornblende-schist (with brown hornblende), between which is a greenish mineral, often serpentinous in aspect, as described in the text (p. 33). ( $\times 12$ .)
5. Serpentine interstreaked with hornblende-schist, which it has partly fused, from Potstone Point (see p. 33). *a*, mostly a rather fawn- or orange-coloured serpentine, including brownish hornblende, etc.; *b*, hornblende-schist with brown hornblende and earthy material (the part dark in the drawing) representing the felspar. ( $\times 9$ .)
6. Another specimen from the same locality, showing a more complete interstreaking of serpentinous (*a*) and hornblendic (*b*) layers, as if the two rocks had flowed together like a slag. ( $\times 9$ .)

## DISCUSSION.

MR. TEALL said that, although he had visited the Lizard several times, he had been unable to form any general theory as to the structure of the district. He was glad to find that, so far as the facts were concerned, there was no serious difference of opinion. The question of the relation of the granulitic series to the serpentine was complicated by the occurrence of veins and dykes of both acid and basic rocks cutting serpentine and gabbro. He could not, in all cases, separate these from the corresponding rocks of the granulitic series. He called attention to photographs and clay models illustrating his theory that the granulitic rocks were of igneous origin, and that many of the peculiar structures were the result of deformation. The Author had accepted the igneous origin of the granulitic rocks, and considered that the deformation took place when the acid rock was intruded.

The main object of the joint paper by himself and Mr. Fox, so far as it related to the section near Ogo-dour, was to call attention to the interbanding of the serpentine and schist, and to the folding which had affected the banded series. He thought that infolds had sometimes been mistaken for intrusive tongues, and he pointed out that transgressive junctions might be produced in connexion with folding. He preferred the interpretation which he and Mr. Fox had arrived at to that proposed by the Author.

Speaking as to the origin of hornblende-schists, he reaffirmed his belief in the theory that both gabbros and basic dykes had been converted into rocks of this character by dynamic metamorphism. He pointed out that in 1887 he had called attention to the existence of a zone of intense mechanical disturbance in the south-western portion of the Lizard, and to the fact that this had been accepted by the Author. The main mass of hornblende-schist lay to the east of this zone: in the same position relative to a zone of disturbance as the Moine Schists of Sutherland. There was a close resemblance in structural features between the main mass of hornblende-schist and the Moine Schist, and he thought it highly probable that this resemblance would be found to be due to dynamic metamorphism.

The Rev. EDWIN HILL said that Messrs. Fox and Teall seemed to imply that granulite had been thrust into serpentine at the Lion Rock, but it appeared to him that the opposite was the case. At Potstone Point he saw no such folding as they seemed to speak of. As for the fact that the bands of included masses of granulite usually follow the external boundaries of the masses, it was most natural to expect that the masses when ripped should yield along the banding as lines of least resistance.

Gen. McMAHON said that, if he understood the Author aright, the latter now believed that no part of the hornblende-schists had originally been ash-beds; if so, he reserved his judgment on that point. In all other respects he was in cordial agreement with the Author. He had not visited the whole area covered by Messrs. Teall and Fox's paper alluded to, and could only speak to the parts of the Lizard actually visited by him. He thought that there had been granitic eruptions at different periods in the Lizard area, and that the intrusion of the granite which had been injected into what is known as the granulitic series was of earlier date than the granite which had invaded the serpentine. As regards the question of the intrusion of the serpentine into the schists, and the granulitic series, his mind was at rest. He had seen several sections which had convinced him as to the correctness of Prof. Bonney's original discovery of the relations of these rocks; and he mentioned, in particular, the section to be seen in the Flagstaff Quarry, Cadgwith, which could not be explained on the hypothesis of the serpentine being caught up in the folds of the granulitic beds.

Sir ARCHIBALD GEIKIE said that he had had the advantage of being conducted over part of the Lizard district by Mr. Fox and Mr. Teall, and though he would not venture to offer an opinion upon most of the disputed questions in the geological structure of that area, he had seen evidence sufficient to convince him that in the Potstone Point part of the coast the serpentine and hornblende-schist formed, as Mr. Teall maintained, a great complex which presented a marked coincidence of banding and had been plicated by one common series of movements. He could see no indication of the serpentine being intrusive in the schists. Without expressing any judgment as to their relative date or mode of origin, he could not doubt that both groups of rock had been simultaneously exposed

to the pressure which had resulted in the marked plication which they both now exhibited.

Mr. J. H. COLLINS said that he had not visited the district referred to by the Author for a dozen years or more, so that his recollection of the facts upon which his opinion was based was rather hazy. He had, of course, read the able papers which had been presented to the Society by several eminent geologists in that period, but had not felt called upon to alter in any important particulars the opinions which he had expressed in 1885 in the 'Geological Magazine.' It was remarkable that so small an area should afford grounds for so great a diversity of opinion: there were almost as many opinions as parties of observers. There were, indeed, some indications of approximation of divergent views; but the approximation was so small during the eighteen years which had elapsed since the reading of Prof. Bonney's first paper, that he feared no one then present would live to witness the general acceptance of the one and only right view which would embrace all the facts.

The AUTHOR said in reply to Mr. Teall that, from the remarks of the latter, it appeared that he still adhered too much to the principle which he (the speaker) thought likely to mislead—namely, restricting the attention to single sections, and dwelling on the minor difficulties presented by them, without regard to the evidence in other parts of the district. Of this the speaker pointed out instances. He thought that Mr. Teall had overstated the amount of banding visible in the serpentines of the Mullion—Ogo-dour district; as a rule (except in the cases mentioned by the Author—what he considered to form a mixture of the two rocks), it was only foliation. As for the Norway peridotites, certain things had been asserted of them, but not proved. Such bending as there was of the rocks about Potstone Point could not be the result of flexure by ordinary mechanical forces; nor could this cause the 'flaser' structure in the gabbros of the east coast. In the former case the weld of the serpentine and hornblende-schist would have been destroyed; in both the serpentine would have been much broken, in the latter crushed, for gabbro is one of the toughest of rocks. On this point his experience in the Alps enabled him to speak with confidence.

4. NOTES *on the GLACIAL GEOLOGY of ARCTIC EUROPE and its ISLANDS.*  
 PART I.: KOLGUEV ISLAND. By Colonel H. W. FEILDEN, F.G.S.  
 With an APPENDIX by Prof. T. G. BONNEY, D.Sc., F.R.S. (Read  
 November 20th, 1895.)

DURING the month of July 1895, after two ineffectual attempts to reach Novaya Zemlya, owing to the great accumulation of ice in Barents Sea, we ran down the edge of the ice-pack, which extended intact from Novaya Zemlya to the northern end of the island of Kolguev. We were fortunate enough to meet with a day so fine and a sea so smooth that our party of five persons landed without difficulty at the mouth of the Gobista River, on the south-western side of Kolguev. Our yacht was sent back to Vardö for coal, and we remained on Kolguev for ten days, encountering very inclement weather. A most opportune break in an almost continuous series of gales and fogs enabled us to leave Kolguev on the return of our vessel, without difficulty or danger.

The island of Kolguev lies in Barents Sea, distant some 50 miles from the mainland of Arctic Russia, and about 130 miles south-west from the nearest part of Novaya Zemlya. Its greatest breadth is about 50 miles, and its extreme length 40 miles; the general shape is oval. The superficial area may be roughly estimated at 2000 square miles. As a familiar comparison, we might liken it in extent to our East Anglian county of Norfolk.

The soundings between Kolguev and the mainland of Europe do not exceed 30 fathoms, while, in all probability, 70 fathoms is the extreme depth between it and Novaya Zemlya. Kolguev, however, differs completely in geological structure from the mountainous islands of Novaya Zemlya, and equally so from the ice-worn rock-area of Russian Lapland, as throughout its entire extent no exposure of basement-rock has been anywhere observed. It is wholly and entirely a vast accumulation of glacio-marine beds.

Let us take a glance at the only geographical map of the island of Kolguev we possess, namely that published by Mr. Trevor-Battye in his valuable book.<sup>1</sup> His stay on the island during 1894 was ten times as long as mine in 1895, and his opportunities of travelling about with the aid of the Samoyeds and their reindeer far exceeded my rambles on foot. He traversed the greater part of the island, while my experiences were confined to its western coastline. I am pleased, however, to find that my observations agree in the main with Mr. Trevor-Battye's remarks on the geological structure of Kolguev; and though I hope to add somewhat to our information regarding the geology of this little-known island, his valuable researches have greatly aided me in verifying my own. Since my return to England I have had the further advantage of consulting Mr. Trevor-Battye on certain points regarding the structure

<sup>1</sup> 'Icebound on Kolguev,' Constable & Co., London, 1895.

of the higher lands of Kolguev; his information, note-book, and sketches were generously placed at my disposal, so that I am able to write with confidence on certain points which otherwise would have partaken more or less of the nature of surmise.

As a general description of Kolguev, that given by Mr. Trevor-Battye cannot be bettered in accuracy or terseness. He writes:—‘The superficial area of the island is sharply divisible into two portions. Speaking generally, the northern two-thirds are high ground, which consists of peat-covered or of bare ridges intersected by gullies, and enclosing small lakes and swamps, and the remaining portion to the south is a dead flat of grass, bog, and peat-levels reaching to the sea.’ He estimates the highest elevations of Kolguev at 250 feet.

In the neighbourhood of the mouth of the Gobista River, where we made our camp, and a mile inland, we found the highest spots about 90 feet above sea-level; and when the atmosphere was clear we could distinctly see the more elevated portion of the island, rising apparently some 10 or 15 miles to the eastward of our station, Mount Sowandeyi and the remarkable, isolated, rounded mass of Mount Bolvana being easily determined. The difference in level between the summit of the clay-cliffs of the western coast and the elevated plateau of the interior cannot be less than 200 feet, consequently the elevated-plateau portion of the island must have been the latest in deposition and the first part to emerge from the sea. It is, therefore, a matter of satisfaction to me that I have obtained from Mr. Trevor-Battye some fuller particulars regarding the formation of Mount Sowandeyi, Mount Bolvana, and the highest points that he visited in the northern plateau, than he has already published (*op. cit.* pp. 392–395). At the highest point that he traversed in the northern portion of the island, and not far from the head-waters of the Pesanka, he found an elevation of 250 feet. At this spot a good section showed from the surface about 80 feet of sand-beds, charged with erratic boulders: these beds of sand rest on clay. At Mount Sowandeyi, some 20 miles directly south, the same formation shows again: the summit of Sowandeyi for a depth of about 80 feet being composed of sand with boulders, immediately underneath which comes the clay. Mount Bolvana, some 5 miles to the south-west, is similarly constructed.

From these observations of Mr. Trevor-Battye, made along a line embracing the greater part of the high plateau of Kolguev, we may reasonably infer that the entire elevated region of the island is composed of beds of sand containing erratic boulders to a depth of not less than 80 feet, and that these sandy beds rest on the Kolguev Clays. Mount Sowandeyi and Mount Bolvana, in my opinion, point to a great marine erosion which must have taken place at the period of their emergence from the sea, for it is hardly possible to doubt that they must have formed at one time a continuous part of the northern plateau. The profile of Mount Bolvana is very singular: it rises as a symmetrical cone above the

tundra, quite detached from the other hills to the northward, like an islet in the sea.

The contour-shading of the elevated plateau in the map attached to Mr. Trevor-Battye's book is drawn rather too abruptly, and is made to extend rather too much to the southward. From what I saw, the elevated region does not extend south of Mount Bolvana, but terminates with Mount Sowandeyi and Mount Lodka. When the highland of Kolguev emerged from the sea, and the island was then about two-thirds of its present size, in all probability Mount Bolvana was its southern apex, and it is easy to understand, if the elevatory process was slow, that the destruction of the soft material of which it is composed might have been effected without difficulty by marine erosion. I think this explanation satisfactorily accounts for the present peculiar shape of Mount Bolvana, and that it was at one time an integral portion of the highland of Kolguev.

The appearance of the western side of Kolguev, though we coasted along it in favourable weather and bright sunshine, is dismal and uninteresting in the extreme. Low, dreary-looking bluffs of clay, of a mournful bluish-grey colour and some 60 to 70 feet high, stretch from the mouth of the Gosena River, at the north-western end of the island, to the mouth of the Gobista; but there is a gentle though perceptible lowering of the coast-line from north to south. At the mouth of the Gobista River the height of the shore-bluffs has dwindled to about 40 feet. From the Gobista to the Kriva, some 6 miles south, the land sinks more rapidly, and at the extreme south-western corner of the island merges with the sea, a considerable portion of the island near the sea-shore being overlain with recent sea-sand.

The margin of the bluffs that form the western shore of Kolguev is not usually a vertical wall of clay, but is generally hidden under a slope or talus which has fallen from above. The destruction of the coast-line would be still more rapid, but for the protection given by the snow-foot which forms upon the sloping talus. This snow-foot is merely an immense accumulation which gathers in the ravines or collects upon the slopes. By the combined action of the sun's rays and the wash of the sea, this snow becomes of an ice-like character, and gives effective aid in protecting the cliffs. Though there are no rivers navigable by the smallest sea-going craft, yet there are three streams of considerable size that discharge on the western side of Kolguev. These are the Gosena, Gobista, and Kriva rivers. I have visited only the last two. In addition there are many smaller rivulets that help to drain this supersaturated island, and as they have cut out for themselves deep ravines, far out of proportion to the volume of water that is carried off by them, they give to the clay-cliffs a varied character, and in passing along the coast we see ravine, and dell, and steep-sided watercourse, which to a certain extent relieve the dreary monotony. These minor ravines, as a rule, are not of any great length. Originating as runnels in the peat of the flat tundra, they act as drains for carrying off the



melted snow and rain-water, but when they approach the shore-bluffs their erosive powers are greatly increased. Not only is there a wearing-out action, but there is an actual eating-back force, so that in the last few hundred yards of their course the stream drops, say, 50 to 60 feet, and cuts out a broad ravine with very steep banks on either side. It was in ravines of this nature that I obtained the chief facilities for examining sections. We find that all these streams in the last part of their course, and when almost on a level with the beach, run over stones and boulders which have been washed out of the surrounding mud-beds. An examination of these stones, which are of every shape and form from angular fragments to rounded and polished blocks, shows that a large proportion are ice-scratched. The medley of rocks represented is remarkable, granites and gneisses, limestones Silurian and Carboniferous, grits, quartzites, porphyries, a variety indeed so great that it would take a trained petrologist to enumerate them. Even the ordinary observer cannot fail to perceive that an immense land-surface has been put under contribution to supply such a diversity of rocks. These boulders vary in size from that of a walnut to large dimensions. One that lay in a stream-bed a few miles north of the Gobista River was a huge block of very hard yellow sandstone, polished, scored, and striated. Along its major axis it had deep flutings cut into it, and in addition it was transversely scratched. It measured 15 feet in length, 9 feet in breadth, and 6 feet in height. When we look around to the mud-and-clay cliffs we see here and there stones and boulders of the same character as those that strew the stream-bed sticking out of the banks, or resting on the talus ready to slide down and join the others below; we also observe that these erratics do not exhibit the slightest tendency to form lines of horizontal deposit in the beds. My opinion is that all have been dropped from floating ice intermittently and tranquilly. The matrix of clay around them shows no signs of disturbance; on falling from the ice-rafts they have sunk gently into the yielding mass, and now they lie throughout the beds looking like currants in a cut loaf.

I have no altogether satisfactory explanation to advance for the presence of such immense numbers of ice-scratched stones as occur in these sedimentary beds of Kolguev. The action of an ice-sheet cannot be invoked at Kolguev; yet, seeing that the ice-scratched stones throughout the Kolguev Beds must in the aggregate amount to millions, one naturally asks, where were they manufactured? Undoubtedly stones frozen into the bottom of floating ice become scratched and polished when stranded on shores where there is sufficient rise and fall to admit of the ice-rafts grating. I have seen this process of manufacture going on.<sup>1</sup> It is, however, difficult to conceive a train of circumstances which admitted of erratics being transported in floe-ice to some rocky

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 566.

coast, there to be scratched and then carried out to sea, and deposited on the floor of the ocean. It seems more reasonable to suppose that this great aggregation of ice-scratched erratics came from glaciers, but the difficulty we have to face is, how do ice-scratched stones get from the glacier to the ice-raft? That ice-scratched stones do find their way into the subaqueous mud-moraines of recent glaciers I can testify, but that is a subject upon which I must not enlarge in this paper. If we admit that the Kolguev erratics came from glaciers, where do we suppose those glaciers to have existed during the period when the Kolguev Beds were deposited?

I should have brought away, had circumstances permitted, a larger number of these erratics from the Kolguev Beds, but our landing and embarkation had to be effected in great haste and in a row-boat. I secured, however, several which I submitted to Prof. Bonney, who has most kindly drawn up a valuable and exhaustive report on the specimens, which appears as an Appendix to this paper (p. 58).

The Kolguev Beds in the vicinity of the Gobista River may be divided into clays and sands, but their differences of composition merge into one another. Not infrequently the clays pass into horizons of a more sandy composition, although so insensibly that it is difficult to determine exactly where the change takes place. The cliffs are so homogeneous in character, and the passage of the clay-stratum into sand is so gradual, that the alteration is evidenced more by the change of colour in the sections than by any definite lines of demarcation. It is evident that no break has occurred in the continuous deposition of these sedimentary beds. In general colour, the Gobista beds remind me of our English Gault. Nowhere did I notice layers of gravel traversing the beds, and in this respect those of Kolguev differ from the glacio-marine beds of Grinnell Land and Smith's Sound. There the horizons of clay, sand, and gravel are often distinctly defined. This arises from their deposition close to land in shallow water. The Kolguev Beds were evidently deposited in the sea, farther from shore than the Grinnell Land beds, and every piece of rock larger than the constituent particles of the beds themselves is, I am convinced, an ice-transported erratic.

The fossils included in the Kolguev Beds (I am not referring to those which have been transported as erratics, but to the fossils contemporaneous with the beds themselves) are all mollusca, and well-known boreal forms, existing at the present time. Though in various sections fragments of *Saxicava arctica*, *Mya*, etc., appeared to be dispersed from top to bottom, yet they were certainly rare, and I obtained but few entire examples. Very likely I was unfortunate in the localities that I investigated; moreover, my stay on the island was brief, and I had necessarily many other duties to occupy my time besides searching for fossils. Still, I submit that these molluscan remains, found in various localities and through the whole

exposed thickness of some of the beds, all of which are (in my opinion) sedimentary, afford proof of their marine origin.

Mr. Edgar Smith has been good enough to carefully examine and name the specimens which I collected, with the following result:—*Natica affinis* (Gmelin) or *N. groenlandica*, Beck; fragments of gasteropod (*Sipho*? sp.); *Saxicava arctica* (Linn.); *Astarte compressa* (Montagu); *Astarte borealis* (Chemn.); *Mya arenaria*, Linn.; fragments of *Mya*, sp.

I am unable to advance any satisfactory theory, either for the paucity of the molluscan remains in the Kolguev Beds, or for the greater part of what I found being fragmentary. I was unsuccessful in finding the remains of any marine vertebrate and equally so in discovering drift-wood in the beds; the latter, it will be remembered, is abundant in the glacio-marine deposits of Grinnell Land.

It may be interesting to compare, and contrast if need be, the Kolguev boulder-clays with the deposits which bear the same name in England and Scotland. To a certain extent all those that we have at home are fragmentary when compared with the boulder-bearing beds of Kolguev, which we may safely assume are 50 miles in length by 40 in width, with a thickness of not less than 250 feet, probably far more, all lying in one undisturbed mass, without the slightest sign of a basement or interrupting rock. Moreover, I met with no deposit in Kolguev precisely similar to what is called 'till' in Scotland. I mean by 'till' a firm, tough, tenacious, strong clay; in the words of Prof. James Geikie, 'so tough indeed does it often become that engineers would much rather excavate the most obdurate rocks. . . . But till has neither crack nor joint—it will not blast, and to pick it to pieces is a very slow and laborious process.'<sup>1</sup> On the other hand, there are many deposits in Britain called 'Boulder Clays' which are in no degree superior in toughness to those of Kolguev, for instance those of the Yorkshire coast; the Chalky Boulder Clays of Norfolk may be also cited as another example. I am inclined to think that the tenacity or the reverse of Boulder Clays depends greatly on the nature of the rocks from which they have been derived. By these remarks I do not wish to imply the impossibility of Till or Boulder Clay being formed as a *moraine profonde* under an ice-sheet; I merely suggest that many Boulder Clays in this country and in other parts of the world may have been deposited under water, and that the transport of their included ice-scratched stones may be due to floating ice. It is suggestive that all the glacial deposits which I have met with in Arctic and Polar lands, with the exception of terminal moraines now forming above sea-level, in areas so widely separated as Smith's Sound, Grinnell Land, Northern Greenland, Spitzbergen, Novaya Zemlya, and Arctic Norway, should be glacio-marine beds. Throughout this broad expanse of the Arctic regions I have come across no beds that could be satisfactorily assigned to the direct action of land-

<sup>1</sup> James Geikie, 'Great Ice Age,' p. 10, London, 1874.

ice: that is to say, beds formed *in situ* by the grinding force and pressure of an ice-sheet. On the contrary, so far as I can judge, the glacial beds which I have traced over the extensive area mentioned above have all been deposited subaqueously and re-elevated.

Nowhere have these facts been more strikingly confirmed than by the investigation of the geological structure of Kolguev. There we find a large island emerging from Barents Sea, showing to my mind evidence, by its sedimentary glacio-marine beds, of the absence of an ice-sheet from the area when these beds were deposited, and its formation under conditions similar to those which at present exist in Barents Sea.

#### APPENDIX.

##### REPORT on the ERRATIC BOULDERS from the KOLGUEV BEDS.

By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S.

- (1)<sup>1</sup> A granitoid rock, with reddish felspar, which, under the microscope, is found to consist of grains, rather fragmental in aspect, of quartz and felspar, and of clustered flakes of biotite. These are cemented by a mosaic, partly of smaller quartz-grains, occurring in patches, which at times also suggest that they may possibly be fragmental, partly of quartz and felspar. These smaller quartz-grains contain a large number of hair-like microliths. The felspar, where distinguishable, is either orthoclase, plagioclase, or (rarely) microcline. The larger grains contain enclosures of quartz or felspar, or a flake or two of biotite. One or two of the smaller crystals are fairly idiomorphic, but as a rule their outline is rather irregular, and they are sometimes bordered by a micropegmatitic zone, of irregular form, which seems to invade the mineral as though it had been the result of a corrosive process acting from without. The biotite occurs in rather small, irregularly-shaped flakes, of which the larger sometimes contain granules of quartz or felspar. These flakes are clustered in a way that suggests the possibility of their representing an original flake of larger size, which has been broken up and subsequently in part reconstructed. There is a little apatite and zircon. I think that the rock has been subjected to a certain amount of mechanical disturbance, which has been followed by reconsolidation. So far as I can form any opinion as to its age, I should judge it to be Archæan.
- (11) A gneissic rock, not strongly banded, consisting chiefly of quartz, a pale reddish felspar, and a dark hornblende. It is very like an Archæan gneiss, such as some of those occurring in Canada, Greenland, etc.
- (13) A rock with a darkish microcrystalline groundmass in which are roundish felspar-crystals, up to about  $\frac{1}{3}$  inch in diameter.

<sup>1</sup> The numbers within parentheses are those placed by Col. Feilden on the specimens.

Under the microscope it is found to consist of an almost microcrystalline groundmass, in which are scattered larger crystalline grains. This groundmass is composed mainly of quartz and feldspar, exhibiting occasionally an approach to a pegmatitic structure, but generally forming a rather irregular mosaic, as if the two minerals had simultaneously crystallized. Interspersed with these, with a rather 'clustered' habit, are numerous needles, apparently of a darkish actinolite, and occasional flakelets of biotite. The larger (porphyritic) crystals are both quartz and feldspar; the former mineral is not abundant, but it occasionally includes a small grain of feldspar or flake of biotite, is sometimes corroded by the groundmass, and is often cracked. The latter mineral, however, exhibits a structure which is not a common one. It contains numerous enclosed grains, often rather rectangular in outline, of another feldspar, and sometimes of quartz, like a 'lustre-mottling.' These enclosures occur somewhat sporadically, *i. e.* they occupy only a part of a crystal. This also, in one or two cases, has evidently increased in size during the last stage of consolidation. We have found, for instance, two planes (perhaps a basal and a clinodome) outlined by minute flakes of biotite, and marking a change in structure, though not in optical continuity. The outer zone, about  $\frac{1}{50}$  inch in maximum breadth, contains a larger number of quartz-enclosures, and these are ranged as if they had grown from the original surface of the crystal, somewhat as the crystals in a granite occasionally group themselves at a junction with another rock. This particular crystal also shows an approach to a micropegmatitic structure, which, however, sometimes passes beyond the boundary. These larger feldspars, as a rule, do not exhibit the oscillatory twinning of plagioclase; one or two are orthoclase, twinned on the Carlsbad type, a few probably are microcline. One or two small zircons are present. The rock would be called by some a quartz-feldsite or quartz-porphry, by others a microgranulite. The general structure (except for the peculiarities of the feldspar) resembles that of the rock figured by Fouqué and Lévy, 'Minéralogie Micrographique,' pl. x. fig. 1).

- (21) A darkish, purple-spotted grit, which, under the microscope, proves to be composed of fragments, subangular to fairly rounded, of minerals and rocks. Among the former are quartz and feldspar, which in one or two cases are associated as if they came from a holocrystalline rock. Among the latter are many fragments of volcanic rocks. These are now devitrified and often rather decomposed, but they evidently were once in a glassy or slaggy condition. Occasionally they are blackened with opacite; feldspar-microliths are present in some. Apparently they represent some of the less acid trachytes—probably andesites; possibly, in one or two cases, even basalts. These exhibit considerable variety, so that they hardly can have come from a single volcano, but nothing worthy of detailed descrip-

tion. A fragment or two of a volcanic grit is also found, and the groundmass contains a little of a carbonate. The rock resembles some of the volcanic grits, which in Britain occur just below (or, as others would say, at) the base of the Cambrian system.

- (2) A rock, apparently similar to the last, but containing two or three pebbles up to  $\frac{3}{4}$  inch in diameter. Two are probably a reddish quartz, a third is green in colour, with colour-zoning, possibly a fine-grained quartzite.
- (19) A fine-grained blackish grit, with several little flakes of mica. Under the microscope it is found to be composed of angular fragments of quartz, felspar, and a mudstone or phyllite, with some flakes of white mica, and, more rarely, of biotite. The felspar is often rather decomposed, and full of tiny flakelets of colourless mica, but plagioclase can be recognized. There is a good deal of a brown staining, some of which may be a hydrocarbon; possibly also a trace of a cleavage making a high angle with the bedding. I cannot say more than that I should conjecture the rock from its general appearance to be Palæozoic.
- A rough vein-specimen, quartz and calcite, apparently from a 'dark slaty rock.'
- (16) A very pale cream-coloured subcrystalline limestone. Under the microscope it is seen to be slightly dolomitic, and composed of irregularly-shaped grains, differing considerably in size. Evidently it once contained rather numerous organisms, but these are too much altered for exact identification. I recognize, however, traces of fragments of lamellibranchs, perhaps one or two small gasteropods, and several foraminifera, not probably representing *Globigerina*, *Orbulina*, and a Rotuline form. I think the rock very likely to be Mesozoic in age. It resembles some of the purer limestones in the Alps, where they have had a sharp 'nip' between the crystallines, and I believe that it has been affected by earth-movements, followed by reconsolidation.
- (6) A piece of purplish-red chert. Under the microscope clear spots or veins appear in a brown-speckled ground. On applying the nicols, the clear constituent throughout the slide is found to be chalcedonic quartz, which here and there in the untinted part (where the granules run larger) shows an approach to a spherulitic structure. The tinting material may be called ferrite, but while some of the larger grains can be recognized as brown iron-oxide, others are pyrite. In this part of the slide small cylindrical bodies can be frequently identified, which, though badly preserved, I believe to be sponge-spicules, and there are possibly indications of other organisms. The rock undoubtedly is a chert, but I cannot determine its age.
- (17) \*Half of a rather large dome-shaped *Favosites gothlandica*

\* As I was anxious that the identification of the fossils should rest on better authority than mine, I submitted the specimens marked with an asterisk to E. T. Newton, Esq., F.R.S., who has kindly named and commented on them.—T. G. B.

(syn. *F. Goldfussi*). As this species ranges from the Silurian into the Devonian, the age is uncertain.

- (3) \* A darkish fossiliferous limestone. 'The greater part of this is made up of *Amphipora* (*Caunopora*) *ramosa*, a Stromatoporiid peculiarly Devonian;' with it a coral, which may be a *Dibunophyllum*, and probably a piece of *Monticulipora*.
- (14) \* Piece of grey limestone containing *Diphyphyllum*.
- \* Eight smallish specimens, very full of fragmental organic remains, seemingly to some extent etched out by action of water. One specimen, measuring about 2 inches by  $1\frac{1}{4}$  inch, contains the spiral arm of a brachiopod (? *Spirifera*), a crinoid stem, and piece of a lamellibranch. In one of the others we find *Polypora*, with fragments, large and small, of Monticuliporids. Similar organisms occur in the rest, one possibly containing *Fenestella*, if it be not *Polypora*. May be Carboniferous in age, possibly older.
- (22) \* A fragment, about  $1\frac{1}{2}$  inch long and not quite  $\frac{3}{4}$  inch wide at the narrower end, of a belemnite, with an excentric alveolus, extending to within  $\frac{1}{4}$  inch of the bottom. [This has since been determined by Mr. G. C. Crick as almost certainly *Belemnites subquadratus*, a species recorded from the Upper Portlandian of the coast opposite Kolguev Island.]

The specimens of an olive-grey fine-grained sandy mudstone, with plant-remains, and of lignite, were submitted to A. C. Seward, Esq., M.A., F.G.S., who has kindly furnished the following notes:—

- '(12) In this specimen, a microscopical examination of the surface reveals the existence of a structure which is probably that of imperfectly silicified coniferous wood. The cavities of the tracheæ appear to have been filled with silica, and present the appearance of delicate and regularly-arranged rods; here and there the series of longitudinally-running rods are crossed by others at right angles, suggesting medullary rays seen in radial view. I am unable to make out any character which will enable me to pronounce a definite opinion as to the geological age of the rock.
- (4) Preservation similar to that in specimen No. 12. Impressions of coniferous wood. The irregularly pitted portions are also, I believe, weathered pieces of wood; a very similar appearance is presented by undoubted specimens of coniferous wood in my possession.
- (5) Fragments of coniferous wood.
- (17) Fragments of carbonized coniferous wood. Sections of a small piece of this wood show fairly well the tracheids and medullary-ray cells characteristic of the Coniferæ, but the preservation is not sufficiently good to enable one to offer an opinion as to the precise nature of the plant.

*Lignite* (A).—A piece of coniferous wood with distinct annual rings. There appear to be large resin-ducts traversing the spring wood longitudinally. Possibly a more complete exami-

nation of thin sections may lead to a generic or even a specific determination.

*Lignite* (B).—A naked-eye examination of this smaller piece of lignite brings out the features of coniferous wood. The annual rings are fairly well marked. In thin slices the tracheids and medullary rays are clearly seen, but the preservation is not sufficiently good for one to recognize the manner of occurrence of the bordered pits. In one slide there are a number of fungal hyphæ distinctly preserved, running irregularly through the woody tissues.

The general impression arrived at from an examination of the specimens is that the rocks are probably Mesozoic in age, and either Jurassic or Wealden. But, without further evidence, it would be rash to offer a more definite opinion as to the geological horizon.'

#### *Ice-worn Stones.*

These are all striated, and in form resemble the ice-worn specimens from a till or boulder-clay. Though I have not used an acid, and scarcely employed the knife, I think the following determinations are correct.

- (2) A fine-grained dark grit, probably identical with (19).
- (9) A slate-grey limestone, apparently a piece of Carboniferous Limestone.
- (18) A dark grey limestone, Carboniferous, or possibly Devonian, not unlike the matrix of (3).
- (15) An almost black compact limestone (? traces of small organisms); very like some of the darker Carboniferous Limestone of Britain.
- (10) A heavy compact brown rock, probably a piece of ironstone (? Carboniferous).

In addition to the above-mentioned specimens are five glass tubes, containing samples of the glacial deposits, described by Col. Feilden; in four cases clay, in the other sand. Small portions of each have been studied under the microscope. In those from the clay I have identified the following minerals:—Fairly common: quartz and felspar (plagioclase and microcline recognized); much more sparingly, a colourless mica, hornblende and augite—both green-coloured, garnet, zircon, iron oxides, and rounded grains of glauconite, some certainly the casts of foraminifera.

The tube marked A was filled with lumps of a rather hard, dark, brownish-grey clay, and in the preparations from it I also found a sponge-spicule. B contained a mixture of a more earthy deposit, nearly the same colour as the clay, with a little grey sand. Here I identified the speckled filmy substance frequently seen in muds and the colourless mica was more abundant. There was also a little biotite and one or two sponge-spicules. C contained a material like A, but a little darker in colour and not quite so coherent. Here too was the filmy substance, as before; also chlorite or a greenish biotite, a sponge-spicule, and one possibly belonging to



some other organism. D contained a rather light grey silty clay; fragments of garnet were rather commoner in this, and one or two rounded prisms of a slightly ferruginous rutile. E contained a fine-grained quartzose sand. This proved to be wholly composed of mineral fragments, mainly quartz; possibly a few chips were from flint. Garnet, colourless mica, glauconite, iron oxide, and sponge-spicules were fairly common. In all these samples the fragments are mostly angular or subangular, a rounded grain, which sometimes is rather larger in size than the rest, only occasionally being found. The materials bear a general resemblance to those forming the Glacial drift of East Anglia.

#### DISCUSSION.

Mr. MARR asked the Author whether there was distinct stratification of the Kolguev Clays. The glacio-marine clays at the end of the Malaspina glacier, and those upraised in the Chaix Hills through that glacier, were well stratified and contained well-preserved shells, as described by I. C. Russel. He called attention to a paper by Torell ('Sveriges Geologiska Undersökning,' 1878), in which the termination of the Scandinavian ice-sheet was carried to Tcheskaya Bay. If it were continued north in the same direction, the ice passing over Lapland, the White Sea, and the Kaninskaia Peninsula might carry eastward Archæan, Devonian, and Carboniferous fragments, such as were stated by Prof. Bonney to occur in the Kolguev Clays.

Mr. TREVOR-BATTYE remarked that he was naturally very glad to find that Col. Feilden's recent observations supported the views which he had himself expressed in the Geological Appendix to his lately published work, 'Ice-bound on Kolguev.' Actual observation on the spot was worth much theory at a distance; and he ventured to believe that no one in that room, if he had had similar opportunities of investigating the Kolguev deposits—the absence of any continuity of rock *in situ*, the astonishing variety of ice-scratched erratics, the composition and relations of sand and clay, the indefinite lines of strata between these, the presence of immense isolated spherical and striated boulders, and the presence of mollusca—could hesitate to believe that these all had been dropped from floating ice, or that the symmetrically conical shape of those isolated hills which he had described in his book was due to later erosion by the sea. The secondary elevation of the island above the waves was interestingly emphasized by (i) the absence from the island of the Arctic hare and the lemming; by (ii) the absence of *Saxifraga oppositifolia*, *Mertensia maritima*—animals and plants of wide Arctic distribution; and, further, by the absence of *Ledum palustre*, a striking feature of the opposite mainland.

Mr. BOULGER pointed out the contrast offered by the deposits on the islands of Solovetsk and Anzersk to those described by the Author in that in the former islands there is nothing but a granitoid gneiss, apparently of Scandinavian origin, in boulders embedded, with some

signs of stratification, in sand of the same composition. If, then, the Kolguev rocks are derived from the Kanin Peninsula, they do not seem to come from the south of east. The raised beaches of Anzersk confirm the indications of recent elevation afforded by Kolguev.

Dr. G. J. HINDE considered that the distinctly striated boulders and the other specimens brought by the Author from Kolguev, indicated that the clays in which they were embedded were of the nature of genuine boulder clay (with which, indeed, the Author had compared them) formed beneath a glacier. It did not seem possible that such an enormous amount of ice-marked material should have been deposited from floating ice. The presence of Arctic mollusca in the clays would not invalidate this conclusion, for similar shells occurred in deposits generally recognized as Till or Boulder Clay.

Dr. GREGORY said that all geologists would welcome the Author's return to the subject of Arctic geology, to which he had already made most important contributions. He thought it necessary, in order to interpret the geology of Kolguev, to consider it in relation to the general problems of North Russian glacial geology. It was generally agreed that there were two centres of glaciation in that region—the Scandinavian, which spread eastward over the Kola Peninsula, and the Tomain-Ural, which flowed westward. These broke up into local glacial centres, and then followed a marine transgression from the north. Russian geologists now attached less importance to sea-borne ice than they formerly did. The erratics described by Prof. Bonney seemed to show that the Kolguev area was within the range of the Scandinavian ice. He referred to several points in Col. Feilden's description, which suggested doubts as to whether Kolguev is wholly composed of marine glacial beds, and to the paper by Tchernychev and Nikitin on the glacial geology and erratics of the adjacent Kanin Peninsula.

The Rev. EDWIN HILL noted the novelty of ice as a protective agent. The East Anglian clays in area and thickness are comparable to those of Kolguev, and not unlike the Author's descriptions; their stones are scratched just as those shown. He asked what were the criteria by which the beds were proved to be marine, for it seemed hard to find any criteria generally admitted by advocates of land-ice. He called attention to the greater value of erratics whose home was near for determining the direction of transport.

The AUTHOR begged to thank the Fellows for the favourable reception of his paper. He was still more obliged for the useful criticisms of Mr. Marr, Dr. Gregory, Dr. Hinde, and the Rev. E. Hill, as in replying to them he could clinch his arguments. Mr. Marr evidently hesitated to accept the Author's determination that Kolguev Island was made up of a vast series of marine beds, laid down without the visible extrusion of a basement-rock, and quoted Prof. Torell's views on the extension of the Scandinavian ice-cap, so as to include the Kanin Peninsula. But this in no way affected the Author's determinations of the Kolguev Beds, for Torell

never visited Kolguev, nor, as far as he was aware, ever propounded any opinion as to the formation of Kolguev, nor as to an extension of the Scandinavian ice-sheet over Barents Sea; consequently Torell's views and those of the Author did not come into conflict. Dr. Gregory and Dr. Hinde apparently thought that the product of an ice-sheet ought to be where the marine beds of Kolguev now are, and questioned the correctness of the Author's determination of the Kolguev Beds. He could assure the Fellows that the Kolguev Beds are as certainly sedimentary beds as the Thanet Sands, or the Thalassic ooze of Barbados. In reply to the Rev. E. Hill, he admitted that he ought, when comparing the extent of the Boulder Clay deposits of England and the glacio-marine beds of Kolguev, to have made it clearer that the comparison was with areas of continuous Boulder Clay without any exposure of a base-rock.

Prof. BONNEY disputed the statement that the ice-scratched stones from Kolguev resembled those of moraines, and said it was an assumption that the glacial beds of East Anglia were the product of land-ice. It was not yet proved that shell-bearing beds were or could be produced by land-ice, and we ought to explain British deposits by those of Arctic regions rather than to follow the reverse process.

5. *On the ALTERATION of certain BASIC ERUPTIVE ROCKS from BRENT TOR, DEVON.* By FRANK RUTLEY, Esq., F.G.S. (Read December 4th, 1895.)

[Abstract.]

Two microscopic sections of rocks occurring on the north side of Brent Tor were examined, and a cursory glance suggested at once the idea that they might originally have consisted to a greater or less extent of extremely vesicular basalt-glass. No unaltered vitreous matter, except perhaps mere traces, can now be detected in these specimens, the interest of which lies in the assemblage of alteration-products which they contain. A third section cut from a small chip collected at the southern side of the base of the Tor consists of a highly vesicular lava of a hyalopilitic character, which may be regarded as an amygdaloidal glassy basalt.

The Author gives a detailed account of the microscopic characters of the three sections, and discusses the history of the rocks, comparing them with Tertiary basic glass, and with the Devonian rocks of Cant Hill, which he described previously. He brings forward evidence in favour of the view that the original alteration of both the Brent Tor and Cant Hill rocks was palagonitic, and that while in the Brent Tor rocks the subsequent alteration of the palagonite into felsitic matter, magnetite, secondary felspar, epidote, and probably kaolin, and some serpentine and chlorite was complete, it was only partial in the case of the Cant Hill rocks. We may therefore assume that palagonite is not the ultimate phase of alteration in basic igneous rocks.

#### DISCUSSION.

Gen. McMAHON enquired whether the Author had worked out in detail the chemical changes involved in the conversion of palagonite into 'felsitic matter' and 'secondary felspar.' He understood the Author to state, and the illustrations exhibited seemed to imply, that palagonite was changed *in situ* into 'felsitic matter' without the addition of any extraneous material; but as the chemical composition of palagonite, as seen in the table on the wall, only showed a total of 8.60 per cent. of aluminium oxide, some explanation as to how this change could be brought about seemed necessary.

Prof. BONNEY said that he thought most of the Author's conclusions would not be disputed, for the changes which had been described had many precedents, though he doubted whether it was possible to trace the mineral alteration of palagonite until it was more precisely defined what is palagonite. But he agreed with Gen. McMahon in thinking that 'felsitic matter' could not be formed from an ordinary palagonite, unless we assumed chemical changes which were not probable.

Mr. W. W. WATTS enquired for further particulars concerning the rock which contained what might possibly be pseudomorphs after leucite. He was interested in this rock, because he had discovered a phonolite with some affinities to that of the Wolf Rock at Blackball Head in Cork. He also asked whether the age of the Brent Tor rocks was definitely known, as the Irish rocks referred to were clearly post-Carboniferous and yet had no affinities with the products of Permian volcanos. Were there any Tertiary volcanic rocks in Devon?

Col. BURTON-BROWN would like the Author to express an opinion of the probable temperature under which these interesting changes in the palagonite were supposed to be taking place.

Dr. HICKS said that some years ago he visited Brent Tor and examined some of the surrounding rocks, and he wished to ask the Author whether he considered the volcanic rocks as of Lower Carboniferous or as of post-Carboniferous age.

Prof. HULL also spoke.

The AUTHOR, in replying to Gen. McMahon's question, stated that basalt-tuffs were very variable in constitution, and in some cases conversion into palagonite might only be partial. One analysis of basalt-glass from Kilauea gave nearly 14 per cent. of alumina. He thanked Prof. Bonney for the kind terms in which he had spoken of the paper, and in reply to his criticism concerning the presence of felsitic matter in the tuffs and lavas of Cant Hill, he pointed out that the amount was comparatively small, and that reserve was entertained about it in the paper, since some of the micro-crystalline matter might be chalcedonic. In answer to Mr. Watts, he stated his belief that the approximately circular sections in some of the Cant Hill rocks were infilled vesicles, although they certainly did bear a general resemblance to the rounded crystals in the leucitites of Monte Albano and of the Capo di Bove, as indicated in the drawings to which Mr. Watts referred. The question of Dr. Hicks with reference to the precise age of the eruptive rocks of Brent Tor was difficult to answer, since the boundary between the Devonian rocks and the Culm was considered very doubtful by Sir Henry De la Beche and had not yet been definitely settled. It was a question for palæontologists to decide. He thought that these eruptive rocks were of Carboniferous age at latest.

6. *The MOLLUSCA of the CHALK ROCK : PART I.* By HENRY WOODS,  
M.A., F.G.S. (Read December 4th, 1895.)

[PLATES II.-IV.]

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I. INTRODUCTION AND LITERATURE.

THE Chalk Rock is a bed of hard, usually cream-coloured limestone, occurring at the top of the Middle Chalk ; it succeeds the zone of *Holaster planus* and is followed by the zone of *Micraster cor-testudinarium*.<sup>1</sup> Noticeable features in the bed are the presence of grains of glauconite and numerous green-coated nodules of phosphatic chalk. Under the microscope it is characterized by the abundance of foraminifera, especially *Globigerina*, and by numerous fragments of the tests of mollusks and echinoids ; the bright green grains of glauconite are also conspicuous. The insoluble residue, obtained by treating with hydrochloric acid, was found by Dr. W. F. Hume to consist mainly of quartz and glauconite ; augite, hornblende, and tourmaline occur very rarely. Frequently the Chalk Rock is not hard throughout, but contains irregular cavities filled with soft mealy chalk or with red sandy clay. Analyses of the rock have been made by M. Duvillier,<sup>2</sup> Dr. Frankland,<sup>3</sup> Mr. C. W. Meanwell and Mr. P. G. Sandford,<sup>4</sup> and they show from .20 to .713 per cent.

<sup>1</sup> In this paper I have adopted the zones given by Mr. Jukes-Browne in Whitaker's 'Geology of London' etc., vol. i. (1889) p. 58 (Mem. Geol. Survey).

<sup>2</sup> Barrois, 'Description géologique de la Craie de l'Île de Wight,' Ann. Sciences Géol. vol. vi. (1875) p. 19.

<sup>3</sup> Penning and Jukes-Browne, 'Geol. of the Neighbourhood of Cambridge,' Mem. Geol. Surv. (1881) p. 66.

<sup>4</sup> 'Handbook of the London Geol. Field Class' (1892), pp. 120, 121.

of phosphoric acid—a large amount compared with that usually found in chalk.

The best development of the Chalk Rock occurs in Berkshire, Oxfordshire, Buckinghamshire, and Bedfordshire; its average thickness is about 3 feet. In the Isle of Wight it varies from 8 inches to 2 feet 7 inches. In Dorset and Devon it consists of a layer of green-coated nodules only. Near Winchester (at Twyford) the zone can be traced by means of the characteristic fossils, but the rock is not hard and does not contain nodules. South-south-west of Marlborough the thickness, according to Mr. Whitaker, is 12 feet. Near Cuckhamsley, on the Berkshire Downs, there are several good exposures of the Chalk Rock, showing a thickness of from 7 to 10 feet, which have yielded numerous fossils. The thickness of the bed at Harts Old Lock (north-west of Pangbourn) is 6 feet, at Aston Rowtant 4 feet, and in Buckinghamshire it varies from 4 feet at Medmenham to 9 feet 10 inches at Prince's Risborough. At Aston Rowtant (and apparently throughout Buckinghamshire and Bedfordshire) there is, at about 20 feet above the Chalk Rock, and separated from it by chalk containing many *Micrasters*, another bed of hard limestone, somewhat similar to the Chalk Rock, but not so thick, and containing fewer fossils. In the cutting on the Midland Railway south of Luton there is an excellent section showing the Chalk Rock and the hard bed above it. The former has a thickness of 2 feet, and is separated from the higher bed by 10 feet of soft chalk. There is a good exposure in a quarry near the station at Boxmoor (Herts) where the rock has a thickness of  $1\frac{1}{2}$  feet; numerous other sections in Hertfordshire occur in the neighbourhood of Hitchin, Baldock, etc. In Cambridgeshire it is seen south of Abington, having a thickness of from 2 to 5 feet, north-west of Westley Waterless 2 to 3 feet thick, and also near Stetchworth. The Chalk Rock is not exposed in Suffolk, and in Norfolk there is one section only, namely, on the railway-cutting west of Little Friars Thorn, where its thickness is 1 foot. Around the Weald the Chalk Rock has been recognized at various places: at Dover it was identified by Mr. W. Hill; near Beachy Head and Lewes it is also present, according to Dr. Barrois; while on the northern side of the Weald it is seen at Guildford, Burham, and elsewhere. In the deep boring at Richmond the Chalk Rock, 5 feet thick, was met with at a depth of 553 feet from the surface. In Lincolnshire and Yorkshire the bed has not been found.

The most striking and interesting feature of the Chalk Rock is its palæontology; in the first place, fossils are very much more abundant in it than in the overlying and underlying beds, and, secondly, the general *facies* of the fauna is peculiar, owing to the presence of genera and species not found in the other zones of the Upper and Middle Chalk, and also to the abundance of certain groups, especially the cephalopoda and gasteropoda, which are comparatively rare in the beds just above and below. As a whole, the fauna presents a much greater resemblance to that of the Lower

Cenomanian than to any which occur in the divisions of the Senonian and Turonian above and below it; and whereas the latter are of a deep-water type, that found in the Chalk Rock is certainly of a comparatively shallow-water character.

The first mention of the Chalk Rock was made by Mr. D. Sharpe in his monograph on the 'Mollusca found in the Chalk of England' (1855, p. 52), where he speaks of it as a 'bed of rather hard chalk, which occurs near the bottom of the Chalk with Flints, and contains *A. peramplus*, *Scaphites*, and several other species of Mollusca hitherto undescribed, and only known in this bed.' But the Chalk Rock was first noticed under that name in the 'Catalogue of the Rock-specimens in the Museum of Practical Geology' published in 1860. A little later a much fuller description appeared in the 'Quarterly Journal' by Mr. Whitaker, who recognized its occurrence in Wiltshire, Berkshire, Buckinghamshire, and Hertfordshire. This author, however, regarded it as occurring between the Upper and Lower Chalk; later writers have taken it to be either the uppermost bed of the Middle Chalk or the lowest of the Upper Chalk.

The Chalk Rock fauna has been recognized at various localities on the Continent. In France it occurs in the Angoumien division. In North-western Germany (Westphalia, etc.) the bed is represented by the zone of *Heteroceras Reussianum*; and in Saxony by the *Scaphites*-beds, and by part of the *Inoceramus Brongniarti*-beds (Pläner-Kalk). In Silesia the Kalk-Mergel of Oppeln belongs to this zone, as do the Teplitz Beds in Bohemia, or at any rate part of them. Lastly, in Bavaria the Pulverthurm Beds (the middle division of the Kagerhöh Beds) are on the same horizon.

On account of the wide distribution of this fauna, and its contrast with that found in the adjacent zones, the Chalk Rock should, I think, receive a separate zonal designation; its palæontological characters are quite as striking, and far more constant than its lithological. Thus for example, at Twyford, near Winchester, as already mentioned, the zone can only be recognized by means of its fossils. Moreover, so far as lithological characters are concerned, the hard bed which occurs above the Chalk Rock in Buckinghamshire and Bedfordshire might with equal propriety be termed 'chalk rock.' If the adoption of a zonal name meet with approval, I would venture to suggest the introduction of the term employed by Prof. Schlüter for the same zone in North-western Germany, viz. 'zone of *Heteroceras Reussianum*,' which for the sake of brevity might be spoken of as simply the '*Reussianum*-zone.' In England *Scaphites Geinitzi* is more abundant than *H. Reussianum*, and would have been preferable for use as a zonal term, but it is not quite confined to the Chalk Rock.

Although several authors [*e. g.* 17, 21, 26, 27, 29 of the bibliographical list, p. 72] have given lists of fossils, no detailed study of the palæontology of the bed has yet been made. In this and the following paper I propose to consider the mollusca, giving an account of the synonymy and distribution of all the species, and also figures and descriptions of the new or not well-known forms. In the



synonymy I shall not, except in a few cases, include references to works in which the species are simply recorded, but only to those in which some description occurs.

The preservation of the fossils in the Chalk Rock is moderately good, but the cephalopoda have scarcely ever the shell preserved. The gasteropoda also occur most frequently as casts, but in nearly every species at least one or two specimens have been found with the shell remaining; and much information has been obtained by taking wax or gutta-percha casts of the external moulds. In *Ostrea* and *Spondylus* (*Dianchora*) the shell is present, but in most of the other lamellibranchs it has disappeared. The brachiopoda and echinoidea have nearly always, as might be expected, the shell preserved. The corals are in the form of casts in almost every case.

My work is based to a large extent on the collection from Cuckshamsley (Berks) made by the late Mr. Montagu Smith, of Trinity College, and presented by his friends to the Woodwardian Museum; but for the loan of many specimens, which have been of much service, I am greatly indebted to several friends and correspondents, of whom I would especially mention Mr. W. Hill, of Hitchin, Dr. J. Morison, of St. Albans, Mr. C. Griffith, of Winchester, and Mr. R. M. Brydone, of New College, Oxford. I have also to thank Dr. A. W. Rowe, of Margate, and Mr. James Saunders, of Luton, for allowing me to examine their collections and for other valuable help; while, in the British Museum and the Museum of Practical Geology, Mr. G. C. Crick and Mr. E. T. Newton have generously helped me in examining the specimens under their charge. Mr. Jukes-Browne has also kindly given me advice concerning the range of some of the species.

In order to study more carefully the species described by Continental palæontologists, I have visited the Museums of Prague, Dresden, Berlin, Hildesheim, Hanover, Brussels, and Paris; and I would here express my gratitude to the authorities of those institutions for the facilities given me.

### *Literature.*

The following is a list of works in which descriptions of the Chalk Rock have appeared:—

1. A. C. RAMSAY, H. W. BRISTOW, H. BAUERMAN, and A. GEIKIE.—‘A Descriptive Catalogue of the Rock Specimens in the Museum of Practical Geology.’ Second edition (1860), p. 296.
2. W. WHITAKER.—‘On the “Chalk Rock,” the topmost bed of the Lower Chalk, in Berkshire, Oxfordshire, Buckinghamshire, etc.’ *Quart. Journ. Geol. Soc.* vol. xvii. (1861) p. 166.
3. E. HULL and W. WHITAKER.—‘The Geology of Parts of Oxfordshire and Berkshire’ (1861), p. 20. *Mem. Geol. Survey.*
4. W. WHITAKER.—‘The Geology of Parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey’ (1864), pp. 5–8. *Mem. Geol. Survey.*
5. W. WHITAKER.—‘On the Chalk of Buckinghamshire and on the Totternhoe Stone.’ *Quart. Journ. Geol. Soc.* vol. xxi. (1865) p. 398.

6. W. WHITAKER.—'On the Chalk of the Isle of Wight.' *Quart. Journ. Geol. Soc.* vol. xxi. (1865) p. 400.
7. J. SAUNDERS.—'Notes on the Geology of South Bedfordshire (No. II.)' *Geol. Mag.* vol. iv. (1867) p. 543.
8. C. EVANS.—'On some Sections of the Chalk between Croydon and Oxstead,' 1870.
9. W. WHITAKER.—'On the Chalk of the Southern Part of Dorset and Devon.' *Quart. Journ. Geol. Soc.* vol. xxvii. (1871) p. 93.
10. W. WHITAKER.—'The Geology of the London Basin. Part I.' (1872), pp. 46, 572. *Mem. Geol. Surv.* vol. iv.
11. C. BARROIS.—'Description géologique de la Craie de l'Île de Wight.' *Ann. Sciences Géol.* vol. vi. (1875) p. 20.
12. C. BARROIS.—'Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande' (1876), pp. 17, 30, 59, 64, 107, 146.
13. E. C. DAVEY.—'Catalogue of Fossils from the Cretaceous Beds of Berkshire' (1877), p. 14.
14. Excursion to Wantage. Report by E. C. DAVEY and W. H. HUDLESTON, *Proc. Geol. Assoc.* vol. v. (1877) p. 139 (also 'Records of Excursions,' p. 285).
15. W. WHITAKER, W. H. PENNING, W. H. DALTON, and F. J. BENNETT.—'The Geology of the N.W. Part of Essex and the N.E. Part of Herts, etc. (1878), pp. 7-9. *Mem. Geol. Survey.*
16. A. J. JUKES-BROWNE.—'The Subdivisions of the Chalk.' *Geol. Mag.* dec. 2, vol. vii. (1880) p. 253.
17. W. H. PENNING and A. J. JUKES-BROWNE.—'The Geology of the Neighbourhood of Cambridge' (1881), pp. 22, 66, 130. *Mem. Geol. Survey.*
18. J. W. JUDD.—'The Nature and Relations of the Jurassic Deposits which underlie London.' *Quart. Journ. Geol. Soc.* vol. xl. (1884) p. 725. [*Chalk Rock*, p. 733.]
19. F. J. BENNETT and J. H. BLAKE.—'The Geology of the Country between and south of Bury St. Edmund's and Newmarket' (1886), p. 3. *Mem. Geol. Survey.*
20. W. HILL.—'On the Beds between the Upper and Lower Chalk of Dover, and their comparison with the Middle Chalk of Cambridgeshire.' *Quart. Journ. Geol. Soc.* vol. xlii. (1886) p. 232.
21. W. WHITAKER.—'The Geology of London and of Part of the Thames Valley,' vol. i. (1889) p. 67. *Mem. Geol. Survey.*
22. Excursion to Boxmoor and Nash Mills. Report by J. HOPKINSON. *Proc. Geol. Assoc.* vol. xi. (1889) p. lviii.
23. Excursion to Upton and Chilton. Report by W. WHITAKER. *Proc. Geol. Assoc.* vol. xi. (1889) p. lxxxviii.
24. A. J. JUKES-BROWNE.—'The Geology of Upton and Chilton in Berks.' *Proc. Geol. Assoc.* vol. xi. (1889) p. 198.
25. H. W. BRISTOW.—'The Geology of the Isle of Wight.' Second edition, by C. REID and A. STRAHAN (1889) p. 73. *Mem. Geol. Survey.*
26. J. MORISON.—'Notes on the Chalk Rock.' *Trans. Herts. Nat. Hist. and Field Club*, vol. v. (1889) p. 199.
27. J. SAUNDERS.—'Notes on the Geology of South Bedfordshire.' *Geol. Mag.* dec. 3, vol. vii. (1890) pp. 121, 124.
28. Excursion to Henley-on-Thames and Nettlebed. Report by J. H. BLAKE. *Proc. Geol. Assoc.* vol. xii. (1891) p. 204.
29. Winchester College Natural History Society. *Geological Section* [List of Chalk Fossils], 1891.
30. A. J. JUKES-BROWNE.—'The Geology of Devizes.' *Proc. Geol. Assoc.* vol. xii. (1892) p. 261, pl. v. f. 2, 4.
31. W. WHITAKER, S. B. J. SKERTCHLY, and A. J. JUKES-BROWNE.—'The Geology of South-western Norfolk and of Northern Cambridgeshire' (1893), p. 39. *Mem. Geol. Survey.*
32. W. F. HUME.—'Chemical and Micro-mineralogical Researches on the Upper Cretaceous Zones of the South of England' (1893), p. 53.
33. W. F. HUME.—'The Genesis of the Chalk.' *Proc. Geol. Assoc.* vol. xiii. (1894) p. 233.

## II. Class CEPHALOPODA.

## Order Nautiloidea.

## Family Nautilidæ, Owen.

Genus NAUTILUS (Breynius, 1732), Linnæus, 1758.

## NAUTILUS SUBLEVIGATUS, d'Orbigny, 1850.

1840. *Nautilus lævigatus*, A. d'Orbigny, 'Paléont. Franç. Terr. Crét.' vol. i. p. 84, pl. xvii.; 1850. H. B. Geinitz, 'Das Quadersandsteingebirge oder Kreidegebirge in Deutschland,' p. 110, pl. iii. f. 2 *a, b*; 1853. D. Sharpe, 'Foss. Mollusca in the Chalk of England,' pt. i. (Ceph.) p. 11, pl. ii. f. 1 *a, b*, 2 *a, b*; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 307; 1863. A. von Strombeck, 'Zeitschr. der deutsch. geol. Gesellsch.' vol. xv. p. 136 (*pars*).

1850. *Nautilus sublævigatus*, A. d'Orbigny, 'Prodrome de Paléont.' vol. ii. p. 189; 1859. F. J. Pictet and G. Campiche, 'Descript. des Foss. du Terr. Crét. de Sainte-Croix' (Pal. Suisse, ser. i. pt. i.), p. 140; 1869. E. Favre, 'Descript. des Mollusques Foss. de la Craie des Environs de Lemberg,' p. 9; 1872. A. Fritsch and U. Schlönbach, 'Ceph. böhm. Kreideformat.' p. 21, pl. xii. f. 1; 1872. H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), pt. ii. p. 182, pl. xxxii. f. 1, 1 *a, 2, 3*; 1873. ? A. Redtenbacher, 'Die Ceph. der Gosauschichten' (Abhandl. d. k. k. geol. Reichsanstalt, vol. v.), p. 95, pl. xxii. f. 1 *a, b*; 1877. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. II. Die Weissenberger und Malnitzer Schichten,' p. 101; 1883. A. Fritsch, *ibid.* III. 'Die Iserschichten,' p. 90; 1889. A. Fritsch, *ibid.* IV. 'Die Teplitzer Schichten,' p. 70; 1891. A. H. Foord, 'Cat. Foss. Ceph. Brit. Mus.' part ii. p. 242; 1893. A. Fritsch, *op. cit.* V. 'Priesener Schichten,' p. 73.

1852. *Nautilus cretaceus*, C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 149; 1858. W. A. Ooster, 'Cat. Céph. Foss. des Alpes Suisses,' pt. iii. p. 14.

*Remarks.*—This species was well described by Sharpe in his monograph on the Mollusca of the Chalk (1853); it is more closely allied to *Nautilus Bouchardianus*, d'Orbigny, than to any other species, but is easily distinguished from it by the absence of an umbilicus. The largest specimen that I have seen from the Chalk Rock was collected by Dr. Morison from the Luton cutting, and has a diameter of  $3\frac{1}{4}$  inches. A mandible, which probably belongs to this species, was obtained by Mr. R. M. Brydone from the Chalk Rock of Winchester.

*Distribution.*—*British Isles*: Lower Greensand; Upper, Middle, and Lower Chalk. Chalk Rock of Oldborough Castle, Cuckhamsley, Luton cutting, Boxmoor, Hitchin, Reed near Royston, and Underwood Hall near Dullingham. White Limestone of the North of Ireland. *France*: zone of *Epiaster brevis* at Fontaine-les-Vervins, zone of *Inoceramus labiatus* east of the Paris basin, and Middle Turonian of Loir-et-Cher. D'Orbigny records it from the Chalk of Martou near Rochfort, and Royan (Charente-Inférieure). *Switzerland*: Alpes d'Appenzell and Alpes de Schwytz. *Belgium*: Maestrichtian of Limbourg (according to Mourlon). *Saxony*: *Inoc. labiatus* beds of Leutewitz and Briessnitz. Pläner-Kalk of Strehlen and Weinböhla; and the *Scaphites*-beds of Zatzschke. *Bohemia*: Turonian<sup>1</sup> and Priesen Beds of various localities, *e. g.* Raudnitz, Teplitz. *Bavaria*: Kagerhöh Beds of Winzerberg, near Regensburg. *Galicia*: Chalk of Nagozany.

<sup>1</sup> In this paper I include in the Turonian the Weissenberg, Malnitz, and Teplitz Beds.

Order **Ammonoidea**.Family **Lytoceratidæ**, Neumayr.Genus **PTYCHOCERAS**, d'Orbigny,<sup>1</sup> 1840.**PTYCHOCERAS SMITHI**, sp. nov. (Pl. II. figs. 1, 2.)

*Description*.—Shell circular in section, ornamented with simple continuous ribs, which become oblique where the shell is recurved. Suture-line imperfectly known; siphonal lobe large; siphonal saddle broad, bifid.

*Affinities*.—*Ptychoceras gaultinus* of Pictet ('Moll. Foss. des Grès Verts des Envir. de Genève,' 1847, p. 139, pl. xv. f. 5, 6) is near to this species, but differs in that the ribs suddenly become much more prominent and distant where the shell is recurved.

*Remarks*.—The type of this species is in the Woodwardian Museum; it is named in memory of the late Montagu Smith.

*Distribution*.—Chalk Rock of Cuckhamsley, and Winchester.

Genus **HAMITES**, Parkinson, 1811.

A fragment of a shell, apparently belonging to this genus, is in the Montagu Smith collection from Cuckhamsley; it has a length of 21 millim., and is provided with ten broad ribs, but is not sufficiently perfect for specific determination.

Genus **HETEROCERAS**, d'Orbigny,<sup>2</sup> 1850.**HETEROCERAS REUSSIANUM** (d'Orbigny), 1850. (Pl. II. figs. 3-5.)

1841. ? *Hamites plicatilis*, F. A. Roemer (*non* Sowerby), 'Verstein. norddeutsch. Kreidegeb.' p. 94, pl. xiv. f. 7; 1843. H. B. Geinitz, 'Die Verstein. von Kieslingswalda,' p. 8, pl. v. f. 2; 1845. A. E. Reuss, 'Verstein. böhm. Kreideformat.' p. 23, pl. vii. f. 5, 6.

1843. *Turrilites polyplocus*, var., H. B. Geinitz, 'Die Verstein. von Kieslingswalda,' p. 8, pl. v. f. 4.

1845. ? *Turrilites Astierianus*, A. E. Reuss, 'Verstein. böhm. Kreideformat.' p. 24, pl. vii. f. 7; 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 345 (*partim*).

1846. *Hamites armatus*, H. B. Geinitz, 'Grundriss der Versteinerungskunde,' p. 304, pl. xii. f. 3; 1850. H. B. Geinitz, 'Das Quadersandst. oder Kreidegeb. in Deutschland,' p. 122 (*partim*); 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 296 (*partim*).

1850. *Hamites Astierianus*, H. B. Geinitz, *ibid.* p. 120 (*partim*).

1850. *Hamites Reussianus*, A. d'Orbigny, 'Prodr. de Paléont.' vol. ii. p. 216.

1850. ? *Turrilites Reussii*, A. d'Orbigny, *ibid.* p. 216.

1850. ? *Turrilites plicatilis*, A. d'Orbigny, *ibid.* p. 216.

1850. *Helicoceras polyplocus*, A. d'Orbigny, *ibid.* p. 216.

1861. *Anisoceras Reussianus*, F. J. Pictet and G. Campiche, 'Descript. des Foss. du Terr. Crét. des Envir. de Ste. Croix' (Paléont. Suisse, ser. 3, part 2), p. 76.

1870. *Helicoceras annulifer*, F. Römer, 'Geol. von Oberschlesien,' p. 320, pl. xxxvi. f. 2.

1871. *Heteroceras Reussianum*, C. Schlüter, 'Ceph. oberen deutsch. Kreide,' p. 109, pl. xxxii. f. 13-21, pl. xxxiii. f. 1; 1878. C. Barrois, Ann. Soc. Géol. du Nord, vol. v. p. 404; 1887. A. Peron, 'Notes pour servir à l'Hist. du Terr. de Craie,' Bull. Soc. Sci. hist. et nat. de l'Yonne, ser. 3, vol. xii. p. 138.

<sup>1</sup> 'Pal. Franç. Terr. Crét.' vol. i. p. 554.

<sup>2</sup> Prodr. de Pal. vol. ii. p. 102.

1872. *Helicoceras armatus*, A. Fritsch and U. Schlönbach, 'Ceph. d. böhm. Kreideformat.' p. 47, pl. xiii. f. 16?, pl. xiv. f. 14-19 (? 14, 15, 16, 18<sup>1</sup>), pl. xvi. f. 9?

1874. *Helicoceras Reussianum*, H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), part ii. p. 193, pl. xxxv. f. 11, 12; 1883. ? A. Fritsch, 'Studien im Gebiete der böhm. Kreideformat. III. Die Iserschichten,' p. 92; 1889. A. Fritsch, *ibid.* IV. 'Die Teplitzer Schichten,' p. 71, f. 44; 1893. A. Fritsch, *ibid.* V. 'Priesener Schichten,' p. 79, f. 62.

*Description*.—Shell spiral, the first few (? 5 or 6) whorls in contact, the later ones free. Whorls circular or slightly elliptical in section, ornamented with distant, oblique, prominent ribs (or varices), each of which is produced at the same levels into four short spines. Between these large ribs are smaller ones, commonly four, but sometimes three, five, or six. All the ribs, particularly the large ones, become less distinct on the inner (anti-siphonal) margin of the whorls.

The suture-line is much divided. Siphonal lobe of moderate size, divided by a median saddle. Superior-lateral lobe larger than the inferior-lateral lobe; superior-lateral saddle a little larger than the siphonal saddle, both narrow-stemmed: these lobes and saddles deeply but not symmetrically bipartite, the divisions also bifid and not symmetrical. Inferior-lateral saddle small, narrow, bipartite. Internal lobe narrow and deep.

*Remarks*.—The specimens found in the Chalk Rock consist in most cases of portions of some of the later whorls only; but one example from S.W. of Dunstable in the Museum of Practical Geology (No. J R 2193) shows two of the earlier whorls in contact. This species has been placed by Schlüter in the genus *Heteroceras*, but by Geinitz, Römer, and Fritsch in *Helicoceras*.

*Distribution*.—*England*: Chalk Rock of Cuckhamsley, Hitchin, Luton cutting, and  $1\frac{1}{4}$  mile S.W. of Dunstable Church. *France*: zone of *Epiaster brevis* at Fontaine-les-Vervins, and east of the Paris basin. *North-western Germany*: confined to the zone of *Het. Reussianum*, found at Salzgitter in Hanover, and Oerlinghausen in the Teutoburger Wald. *Saxony*: Pläner-Kalk of Strehlen, and Weinböhla. *Silesia*: *Scaphites*-beds of Oppeln. *Bohemia*: Turonian and Priesen Beds of numerous localities, *e. g.* Priesen, Kistra, Hundorf.

## HETEROCERAS, sp. (Pl. II. figs. 6-8.)

*Description*.—Shell dextral or sinistral. Whorls elliptical in section, crossed by deep oblique furrows (two or three on each whorl), and ornamented with transverse, simple, oblique ribs; on some of the earlier whorls the direction of the obliquity changes, so that the ribs of one whorl make with those of the next an angle of about 120°; the change takes place at one of the furrows. Umbilicus very wide.

Suture-line much ramified; siphonal lobe of moderate size, with a median saddle. Superior-lateral lobe twice as large as the

<sup>1</sup> Figures 14, 15, and 16 are referred by Schlüter to *Helicoceras reflexum* (Quenstedt).

inferior-lateral lobe, both deeply divided, the divisions bifid and not quite symmetrical. Siphonal saddle a little larger than the superior-lateral saddle, both narrow-stemmed and deeply and unsymmetrically divided.

*Affinities.*—This species is near to *Astierianus* of d'Orbigny<sup>1</sup> from the Upper Gault of Escagnolle, but it is distinguished by the wider umbilicus and by the change in direction of the ribs on some of the whorls. It is also allied to *Helicoceras indicum*, Stoliczka,<sup>2</sup> from the Arrialoor Group of Vegahoor, with which it may prove to be identical when that form is better known. *H. Reussianum* differs in having the varices continued on the spire, just as on the free whorls.<sup>3</sup>

*Distribution.*—Chalk Rock of Winchester, Lichfield (Hants), Cuckhamsley, Luton cutting, and Hitchin.

### Genus BACULITES, Lamarck, 1801.

BACULITES BOHEMICUS, Fritsch and Schlönbach, 1872. (Pl. II. figs. 9, 10.)

1843. *Baculites anceps*, H. B. Geinitz, 'Die Verstein. von Kieslingswalda,' p. 9.

1850. *Baculites baculoides*, H. B. Geinitz, 'Das Quadersandst. oder Kreidegebirge in Deutschland,' p. 122; 1874. H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), part ii. p. 195, pl. xxxv. f. 17-21.

1872. *Baculites Faujassi*, Lamarck, var. *bohémica*, A. Fritsch and U. Schlönbach, 'Ceph. der böhm. Kreideformat.' p. 49, pl. xiii. f. 23-25, 29, 30; 1893. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. V. Priesener Schichten,' p. 80, f. 63; 1895. J. J. Jahn, Jahrb. der k. k. geol. Reichsanst. vol. xlv. p. 133, pl. viii. f. 8.

1875. *Baculites bohemicus*, C. Barrois, Ann. Soc. Géol. du Nord, vol. v. p. 403.

1876. *Baculites cf. bohemicus*, C. Schlüter, 'Ceph. oberen deutsch. Kreide,' p. 140, pl. xxxix. f. 1-5.

*Description.*—Shell increasing in diameter very slowly, section elliptical, siphonal margin rounded; last chamber with a curved projecting portion on the siphonal side. Surface of shell with faintly marked ribs or undulations, which pass over the siphonal margin, where they are strongest, and curve posteriorly on the lateral areas, becoming indistinct or altogether disappearing on the anti-siphonal margin. There are also at intervals broad furrows, which run parallel to the ribs and become less distinct on the anti-siphonal margin (these, however, are not seen on all specimens).

*Suture-line.*—siphonal lobe rather broad, divided by a median saddle; superior-lateral lobe rather deep, bifid, larger than the inferior-lateral; internal (anti-siphonal) lobe small; siphonal saddle broad, deeply bifurcate, each part being also bifid; lateral saddles similarly bifurcate, the superior-lateral being about half the size of the siphonal saddle.

*Affinities.*—This species is related to *Baculites vertebralis*, Lamk. (= *Faujasi*, Lamk.), and to *B. baculoides*, Mant. It differs from *B. vertebralis* in having the siphonal saddle nearly twice as broad as the superior-lateral saddle, and the ribs and grooves appear to be

<sup>1</sup> 'Pal. Franç. Terr. Crét.' vol. i. (1840) p. 578, pl. cxl. f. 8-11.

<sup>2</sup> 'Foss. Ceph. Cret. Rock. S. India' (1866), p. 184, pl. lxxxvi. f. 1-2.

<sup>3</sup> See Schlüter, 'Ceph. oberen deutsch. Kreide' (1871), pl. xxxii. f. 14-16, 20.

better marked. The suture-line of *B. baculoides* has not been observed in English specimens; but the figure given by d'Orbigny from a French example differs from *B. bohemicus* in the greater length of the lobes and saddles, and in having the siphonal saddle and the superior-lateral saddle of about the same size.

*Remarks.*—Geinitz considers that *B. bohemicus* is identical with *B. baculoides* of Mantell, which is found in the Lower Chalk of Sussex, etc., and he regards the forms figured under the same name by d'Orbigny from the French Cenomanian as distinct, proposing to place them in his species *sub-baculoides*; he takes as his types specimens found on the same horizon in Saxony. The specimen from the Priesen Beds of Bohemia figured by Fritsch (1893) is of great interest, as it shows the earliest part of the shell with the initial chamber. The examples of *B. bohemicus* found in the Chalk Rock are far from perfect, and the mode of preservation often leaves much to be desired; the longest portion that I have seen measured 87 mm., with a thickness of 9 mm. and a height of 12 mm.

*Localities.*—*England*: Chalk Rock of Winchester, Lichfield (Hants), Cuckhamsley, Boxmoor, and Luton. *France*: zone of *Terebratulina gracilis* east of the Paris basin, zone of *Epiaster brevis* at Fontaine-les-Vervins. *North-western Germany*: zone of *Heteroceras Reussianum* at Oerlinghausen, Langelsheim, Heiningen, etc., and rarely in the zones of *Inoceramus Brongniarti* and *I. Cuvieri*. *Saxony*: Pläner-Kalk (zone of *I. Brongniarti*) of Strehlen and Weinböhla. *Bohemia*: Turonian and Priesen Beds of Priesen, Waldeck, Böhmisch-Kamnitz, and Leneschitz.

### Family Prionotropidæ, Zittel.

#### Genus PRIONOCYCLUS, Meek,<sup>1</sup> 1872.

PRIONOCYCLUS NEPTUNI (Geinitz), 1849. (Pl. II. fig. 11, and Pl. III. figs. 1-4.)

1842. *Ammonites falcatus*, H. B. Geinitz (*non* Mantell), 'Char. der Schichten u. Petrefacten der sächs.-böhm. Kreidegeb.' (Heft 3), p. 67.

1850. *Ammonites Neptuni*, H. B. Geinitz, 'Das Quadersandst. oder Kreidegebirge in Deutschland,' p. 114, pl. iii. f. 3; 1872. C. Schlüter, 'Ceph. oberen deutsch. Kreide,' p. 36, pl. xi. f. 1-7; 1872. A. Fritsch and U. Schlönbach, 'Ceph. böhm. Kreideformat.' p. 30, pl. iii. f. 4, pl. xiv. f. 3; 1874-5. H. B. Geinitz, 'Das Elbthalgebirge' (Palaeontographica, vol. xx.), pt. 1, p. 280, pl. lxii. f. 4; pt. 2, p. 185, pl. xxxvi. f. 4; 1877. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. II. Die Weissenberger und Malnitzer Schichten,' p. 101; 1887. A. Peron, 'Notes pour servir à l'Hist. du Terr. de Craie,' Bull. Soc. Sci. hist. et nat. de l'Yonne, ser. 3, vol. xii. p. 136.

1855. ? *Ammonites Bravaisianus*, D. Sharpe, 'Foss. Mollusca in the Chalk of England' (Ceph.), p. 52, pl. xxiii. f. 8, 9.

*Description.*—Shell discoidal, carinate, with a wide umbilicus. Whorls rather more than one-third enclosing, subquadrangular in section, ornamented with very strong and slightly oblique ribs, each of which bears near the siphonal margin two tubercles, the inner

<sup>1</sup> F. B. Meek, in Hayden's Ann. Rep. U.S. Geol. Survey of the Territories (1872), p. 298 (footnote), and *ibid.* vol. ix. (1876) p. 452.

being a little the smaller. After passing the inner tubercle the ribs bend forward to the outer, and again forward to the carina. The carina is strongly dentate, one tooth corresponding to each rib. The ribs are of two sizes<sup>1</sup>; the longer ones start from the umbilical margin and bear there a small tubercle, but the smaller ones, which alternate with these, begin a short distance from the margin and do not bear at the starting-point a tubercle.

Suture-line: the lobes and saddles not much divided, the saddles much larger than the lobes. Siphonal saddle larger than the superior-lateral and unsymmetrically bipartite. Siphonal lobe rather deep, divided by a saddle; superior-lateral lobe larger than the preceding and with unsymmetrical lobules; inferior-lateral lobe about half the size of the superior-lateral.

*Affinities.*—This species is related to *Ammonites Germari* of Reuss,<sup>2</sup> but is distinguished from it by the dentation of the carina being much coarser. *A. dentato-carinatus* of Römer<sup>3</sup> differs from this in having only one row of tubercles near the siphonal margin. *P. Neptuni* is distinguished from the young forms of *Ammonites Woolgari*, Mantell, by the greater breadth of the ribs. Sharpe described and figured as *Ammonites Bravaisianus*, d'Orbigny, two specimens from the Middle Chalk (probably Chalk Rock) of Dover, which are probably identical with the species under consideration; the originals were in the collections of Mr. J. W. Flower and Mr. S. J. Mackie, but I have not been able to see them.

D'Orbigny's *Ammonites Bravaisianus*, from the 'grès vert supérieur' of Uchaux and Mondragon (Vaucluse), resembles *P. Neptuni* in the form of the shell and the ribs, but the carina is entire. D'Orbigny's types are preserved in the Palæontological Laboratory of the Paris Museum; the largest has a diameter of 17 mm. The figures given in the 'Paléontologie Française' do not convey quite a correct idea of the form of the ribs.

*Localities.*—*England*: Chalk Rock of Oldborough Castle, Cuckhamsley, Prince's Risborough, Luton cutting, Dunstable, and Hitchin. *France*: zone of *Holaster planus* in the Yonne, zone of *Epiaster brevis* of Saint-Clément, zone of *Terebratulina gracilis* east of the Paris basin, Senonian (F of M. Lambert) of Armeau. *North-western Germany*: confined to the zone of *Het. Reussianum*, found at Bielefeld, Ringeburge, Heiningen, and Windmühlenberge near Salzgitter. *Saxony*: in the Mergelschichten (*I. Brongniarti*-beds) of Walkmühle near Pirna; Geinitz records one specimen from the Pläner (Cenomanian) of Plauen, near Dresden. *Bohemia*: Malnitz Beds, near Laun.

<sup>1</sup> In some specimens (*e. g.* Pl. III. fig. 3) the difference in size of the ribs is very slight.

<sup>2</sup> A. E. Reuss, 'Die Verstein. d. böhm. Kreideformat.' 1845, p. 22, pl. vii. f. 10. See also A. Fritsch and U. Schlönbach, 'Ceph. böhm. Kreideformat,' p. 29, pl. xiv. f. 1, 2, pl. xvi. f. 7; and C. Schlüter, 'Ceph. oberen deutsch. Kreide,' p. 41, pl. xi. f. 15-17.

<sup>3</sup> F. Römer, 'Die Kreidebild. v. Texas,' 1852, p. 33, pl. i. f. 2.



## Family Desmoceratidæ, Zittel.

Genus *PACHYDISCUS*, Zittel, 1884.*PACHYDISCUS PERAMPLUS* (Mantell), 1822.

1822. *Ammonites peramplus*, G. Mantell, 'Foss. S. Downs,' p. 200 1822. J. Sowerby, 'Min. Conch.' vol. iv. p. 79, pl. cccvii.; 1840. A. d'Orbigny, 'Paléont. Franç. Terr. Crét.' vol. i. p. 333, pl. c. f. 1, 2; 1841. F. A. Römer, 'Die Verstein. des norddeutsch. Kreidegeb.' p. 87; 1842. H. B. Geinitz, 'Char. der Schichten u. Petrefacten des sächsisch-böhm. Kreidegeb.' Heft 3, p. 67, pl. xii. f. 2; 1845. A. E. Reuss, 'Die Verstein. d. böhm. Kreideformat.' p. 21; 1846. H. B. Geinitz, 'Grundr. der Verstein.' p. 297 (*partim*); 1846. F. v. Quenstedt, 'Petrefact. Deutschlands,' vol. i. Ceph. p. 216; 1850. A. d'Orbigny, 'Prodr. de Paléont.' vol. ii. p. 189; 1850. H. B. Geinitz, 'Quadersandstein. oder Kreidegeb. in Deutschland,' p. 116, pl. v. f. 1, 2, 3; 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 423; 1853. D. Sharpe, 'Foss. Mollusca in the Chalk of England' (Ceph.), p. 26, pl. x. f. 1-3; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 298; 1859. A. v. Strombeck, 'Zeitschr. der deutsch. geol. Gesellsch. vol. xi. p. 44; 1860. W. A. Ooster, 'Cat. Céph. Foss. des Alpes suisses,' part iv. p. 150; 1860. F. J. Pictet and G. Campiche, 'Foss. du Terr. Crét. de Ste-Croix,' Pal. Suisse, pt. i. p. 354; 1865. F. Stoliczka, 'Foss. Ceph. Cret. Rocks S. India,' p. 130, pl. lxx. f. 1, 2; 1866. C. Schlüter, 'Zeitschr. der deutsch. geol. Gesellsch. vol. xviii. p. 71; 1870. F. Römer, 'Geol. von Oberschlesien,' p. 319, pl. xxxv. f. 5; 1870. C. Schlüter, 'Neues Jahrb. für Min. etc. p. 945; 1872. C. Schlüter, 'Ceph. ober. deutsch. Kreide,' p. 31, pl. x. f. 7-14; 1872. A. Fritsch and U. Schlönbach, 'Ceph. der böhm. Kreideformat.' p. 38, pl. viii. f. 1-4, pl. xiv. f. 4, 5; 1874. H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), part ii. p. 189, pl. xxxiv. f. 4-7; 1877. A. Fritsch, 'Studien im Gebiete der böhm. Kreideformat. II. Die Weissenberger und Malnitzer Schichten,' p. 102; 1883. Fritsch, *ibid.* 'III. Die Iserschichten,' p. 91; 1878. F. Dixon, 'Geol. Sussex,' ed. 2, p. 386, pl. xxvii. f. 22; 1878. C. Barrois, 'Ann. Soc. Géol. du Nord, vol. v. p. 403.

1840. *Ammonites Prosperianus*, A. d'Orbigny, 'Paléont. Franç. Terr. Crét.' vol. i. p. 335, pl. c. f. 3, 4; 1850. F. Dixon, 'Geol. Sussex,' p. 359, pl. xxvii. f. 22; 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 424.

1840. *Ammonites lewesiensis*, H. B. Geinitz, 'Char. der Schichten u. Petrefacten des sächs. Kreidegeb.' Heft 2, p. 39, pl. xii. f. 2 (*partim*).

1842. *Ammonites Decheni*, H. B. Geinitz, 'Char. der Schichten u. Petrefacten des sächsisch-böhm. Kreidegeb.' Heft 3, p. 66 (*partim*); 1846. H. B. Geinitz, 'Grundr. der Verstein.' p. 297 (*partim*).

1852. ? *Ammonites flaccidicostata*, F. Römer, 'Die Kreidebildungen von Texas,' p. 33, pl. i. f. 1 a, b.

1865. ? *Ammonites Vaju*, F. Stoliczka, 'Foss. Ceph. Cret. Rocks S. India,' p. 132, pl. lxx. f. 3.

1869. (?) *Ammonites fraternus*, W. M. Gabb, 'Geol. Survey of California: Palaeontology, vol. ii. p. 137, pl. xxiii. f. 15, 15 a, b.

1873. ? *Ammonites Draschei*, A. Redtenbacher, 'Die Ceph. der Gosauschichten,' Abhandl. d. k. k. geol. Reichsanstalt, vol. v. p. 123, pl. xxx. f. 1 a, b.

1889. *Ammonites (Pachydiscus) peramplus*, A. Fritsch, 'Studien im Gebiete der böhm. Kreideformat. IV. Die Teplitzer Schichten,' p. 70, f. 41; 1893. Fritsch, *ibid.* 'V. Die Priesener Schichten,' p. 76.

*Description.*—Shell discoidal, whorls very convex, about two-thirds enclosed, siphonal area rounded. Umbilicus deep, walls almost vertical. Ribs well-marked, rounded, curving forwards, and continuous on the siphonal area. At the umbilical margin of each whorl there are six or seven prominent sharp tubercles, each of which gives rise to one, or occasionally two, primary ribs; between these there are usually three (but sometimes more or fewer) smaller ribs which start from the middle of the lateral area of the whorl.

The suture-line is figured by Sharpe (pl. x. f. 2 a) and by Geinitz (1874, vol. ii. pl. xxxiv. f. 7); the superior-lateral lobe is trifurcate, a little larger than the inferior-lateral, which is also trifurcate; siphonal and lateral saddles bipartite, superior-lateral a little larger

than the siphonal saddle, inferior-lateral about two-thirds the size of the superior-lateral saddle.

In older individuals the whorls become more flattened, and the tubercles and ribs (11 to 14 on the last whorl) less distinct; the latter are less curved and all start from the tubercles at the margin of the umbilicus and often disappear on the siphonal area. In senile forms the shell is quite smooth.

*Remarks.*—The average diameter of this species in the Chalk Rock is  $1\frac{1}{2}$  inch; Dr. Morison has a specimen 8 inches in diameter from the Luton cutting. In the zones of the Middle Chalk below the Chalk Rock it is often much larger, being sometimes more than a foot in diameter. In one or two cases only have I seen portions of the shell preserved.

The specimens described by Mantell came from near Lewes and Eastbourne; and, although he gave no figures, there can be no doubt whatever about the identity of the species. Had there been any, it would be removed by the fact that the specimen figured by Sowerby a year later in the 'Mineral Conchology' was presented to him by Mantell himself. Sowerby gave only one figure, that of a rather old individual 9 inches in diameter. D'Orbigny figured in the 'Paléontologie Française' the adult and young forms under the names of *Ammonites peramplus* and *Ammonites Prosperianus* respectively; at the same time, he stated that the latter might be a young individual of the former, but not having been able to observe a passage between the two, he would regard them as distinct species. However, almost all later authors, except Dixon ('Geol. Sussex,' 1850), have considered *Prosperianus* as a synonym of *peramplus*. Good figures of this species, showing examples of different ages, are given by Sharpe; his specimens came from the Middle Chalk (probably Chalk Rock) of Hertfordshire and Wiltshire.

Specimens from the Trichinopoly Group of the north-west of Annapaudy referred to this species are described and figured by Stoliczka; but these differ from the European examples in the smaller ribs forming a tubercle 'at the point where they are curved forward.' Stoliczka remarks (p. 131), 'D'Orbigny's *Am. peramplus* seems to differ very considerably from the original English figures, while his *Am. Prosperianus* is identical with them.' This is certainly an erroneous observation, for Sowerby's figure agrees very closely with D'Orbigny's *peramplus*. Stoliczka also figures under the name of *Ammonites Vaju* a specimen from the Trichinopoly Group of the north-west of Annapaudy, which, if not identical with *peramplus*, is certainly its representative form.

*Ammonites flaccidicostata*, described by Römer from Guadalupe in Texas, is near to *peramplus*, but it has only one small rib between the larger ones.

*Ammonites fraternus* of Gabb, from the Martinez group of Benicia, California, differs only in the form of the suture-line—the siphonal saddle is more divided than in *peramplus*, and is larger than the superior-lateral saddle.

The form described by Redtenbacher under the name of *Ammonites*

*Draschei*, from the Gosau Beds, is probably identical with *peramplus*, but the suture-line is rather different.

The older individuals of *P. peramplus* resemble closely Mantell's *Am. lewesiensis*; but, according to Sharpe,<sup>1</sup> 'the young of the two species have no resemblance, *A. lewesiensis* being nearly smooth, and the other ornamented with numerous ribs.'

The types of *Pachydiscus peramplus* cannot be identified with certainty, since Mantell gave no figures; but specimens in his collection in the British Museum agree well with his description. Sowerby's specimen is not in the British Museum, nor is the one figured by Dixon. One of the examples figured by Sharpe is in the Museum of the Geological Society; and of the others, which were collected by Mr. W. Cunningham, one (fig. 3) is in the British Museum.

*Distribution*.—*England*: Middle Chalk. Chalk Rock of Winchester, Arn Hill near Warminster, Aston Rowtant, Prince's Risborough, Berkhamstead, Boxmoor, Luton railway-cutting, Dunstable, Hitchin, Barkway, Reed near Royston, and Underwood Hall near Dullingham.

*France*: zones of *Rh. Cuvieri* and *P. peramplus* in the Loir-et-Cher, zone of *Ter. gracilis* east of the Paris basin, zone of *Epiaster brevis* at Fontaine-les-Vervins, zone of *Micr. breviporus* in the Yonne. *Switzerland*: Alps of Appenzell. *North-western Germany*: common in the zone of *Het. Reussianum* and found near Salzgitter, at Heinigen near Börsum, Klein-Döhren near Liebenburg, and Rheine in Westphalia. Rare in the zone of *Inoc. Brongniarti*, at Buren in Westphalia, etc. Also rare in the zone of *Inoc. Cuvieri* of Rothenfelde, and Windmühlebergen near Salzgitter. *Saxony*: Pläner-Kalk of Strehlen and Weinböhla. *Inoc. labiatus*-beds of Rottwernsdorf and Leutewitz. *Silesia*: *Scaphites*-beds of Oppeln. *Bohemia*: Ranges through the Turonian and the Priesen Beds, found at Teplitz, Lenešic, Lobositz, Popelz, etc. *Bavaria*: Kagerhöh Beds of Galgenberg, Winzerberg, and Kagerhöh.

[Systematic position uncertain.]

Genus SCAPHITES, Parkinson, 1811.

SCAPHITES GEINITZI, D'Orbigny, 1850. (Pl. III. figs. 5–7.)

1840. *Scaphites aequalis*, H. B. Geinitz, 'Charakt. der Schichten u. Petrefacten der sächsischen Kreidegeb.' Heft 2, p. 40; 1845. A. E. Reuss, 'Verstein. böhm. Kreideformat,' p. 23; 1846. H. B. Geinitz, 'Grundriss der Versteinerungskunde,' p. 301, pl. xii. f. 1 (*partim*); 1850. H. B. Geinitz, 'Das Quadersandsteingebirge oder Kreidegeb. in Deutschland,' p. 116 (*partim*); 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 331 (*partim*).

1841. *Scaphites costatus*, F. A. Römer, 'Verstein. norddeutsch. Kreidegeb.' p. 90; 1842. H. B. Geinitz, 'Charakt. der Schichten u. Petrefacten der sächsisch-böhm. Kreidegeb.' Heft 3, p. 67; 1865. F. A. Römer, 'Die Quadraten-Kreide des Submerberges bei Goslar,' Palaeontographica, vol. xiii. p. 198.

1841. *Ammonites Cottæ*, F. A. Römer, 'Verstein. norddeutsch. Kreidegeb.' p. 86, pl. xiii. f. 4; 1845. A. E. Reuss, 'Verstein. böhm. Kreidef.' p. 21, pl. vii. f. 11.

1850. *Scaphites Geinitzi*, A. d'Orbigny, 'Prodrome de Paléont.' vol. ii. p. 214;

<sup>1</sup> Sharpe, 'Foss. Moll. in Chalk of England (Ceph.),' p. 46.

1861. F. J. Pictet and G. Campiche, 'Descript. des Foss. du Terr. Crét. des Envir. de Sainte-Croix,' Paléont. Suisse, ser. 3, pt. ii. p. 21; 1865. F. A. Römer, 'Die Quadraten-Kreide des Submerberges bei Goslar,' Palaeontographica, vol. xiii. p. 198; 1866. C. Schlüter, Zeitschr. d. deutsch. geol. Gesellsch. vol. xviii. p. 73; 1868. C. G. Gümbel, 'Geogn. Beschreib. des Königreichs Bayern,' vol. ii. p. 764; 1870. F. Römer, 'Geol. von Oberschlesien,' p. 320, pl. xxxv. f. 6; 1872. C. Schlüter, 'Ceph. d. ober. deutsch. Kreide,' p. 75, pl. xxiii. f. 12-22, pl. xxvii. f. 9; 1872. A. Fritsch and U. Schlönbach, 'Ceph. böhm. Kreideformat.' p. 42, pl. xiii. f. 7, 8, 10, 12, pl. xiv. f. 11; 1874. H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), part ii. p. 191, pl. xxxv. f. 1-4; 1877. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. II. Die Weissenberger und Malnitzer Schichten,' p. 102; 1883. Fritsch, *ibid.* 'III. Die Iserschichten,' p. 92, f. 53; 1889. Fritsch, *ibid.* 'IV. Die Teplitzer Schichten,' p. 71, f. 43; 1893. Fritsch, *ibid.* 'V. Die Priesener Schichten,' p. 76; 1895. J. J. Jahn, Jahrb. der k. k. geol. Reichsanst. vol. xlv. p. 133, pl. viii. f. 3. 1855. *Ammonites wiltonensis*, D. Sharpe, 'Foss. Moll. in the Chalk of England,' (Ceph.) pt. i. p. 53, pl. xxiii. f. 10 a-c.

1865. *Scaphites striatus*, F. A. Römer, 'Die Quadraten-Kreide des Submerberges bei Goslar,' Palaeontographica, vol. xiii. p. 198.

1868. *Scaphites Cottai*, C. G. Gümbel, 'Geogn. Beschreib. des Königreichs Bayern,' vol. ii. p. 764.

*Description.*—Shell flattened, or sometimes rather convex; siphonal margin rounded. The greatest width is attained in the straight part of the shell, midway between the involute part and the recurved portion; the inner margin of this part is nearly straight, the siphonal margin is regularly convex. The surface of the shell is ornamented with numerous ribs which are continuous across the siphonal margin; the number and proximity of these vary somewhat in different specimens. On the involute portion of the shell there are between two and three times as many on the siphonal area as on the lateral area; this is due partly to the fact that the ribs in many cases bifurcate before the siphonal area is reached, and partly to the intercalation of new ribs. On the lateral area of the evolute part, and slightly nearer the siphonal than the internal margin, is a row of from seven to nine rather blunt tubercles, which commences at about the middle of the straight part and ends before the aperture is reached. Each tubercle gives rise on the inner side to a single rib, and on the siphonal side to a pair of ribs, and between these pairs one, or sometimes more, ribs are intercalated. Between the last tubercle and the aperture of the shell, the ribs originate from the inner margin of the whorl, sometimes bifurcating, sometimes remaining single. In a few specimens the row of tubercles is rather indistinct.

In one small specimen the aperture of the shell has a projecting lip. The body-chamber commences where the shell becomes evolute.

Suture-line: saddles much broader than the lobes. Siphonal lobe large and deep, about twice the size of the superior-lateral lobe, which is bifid, inferior-lateral lobe small, trifurcate. Siphonal saddle broad, bipartite, the outer division larger than the inner. Superior-lateral saddle about half the size of the siphonal saddle, bipartite and not quite symmetrical. Inferior-lateral saddle smaller, slightly bifid.

*Remarks.*—The largest example that I have seen has a length of 45 mm. There are two forms of this species, a thick and a thin one, and these can be distinguished in individuals of all sizes; it is possible that the difference may be due to sex.

This form was first described by Geinitz, who, however, referred

it to *S. æqualis* of Sowerby. D'Orbigny recognized it as being distinct, and gave it the name *Geinitzi*, but it was first figured as such by Römer (1870). Later figures and descriptions have been given by Schlüter, Fritsch, and Geinitz.

*Ammonites Cotte* of Römer (1841) has been shown to be simply the involute part of *Scaphites Geinitzi*. The same, I believe, is the case with Sharpe's *Ammonites wiltonensis*; the type of this species was collected by Mr. W. Cunningham from the Chalk Rock of Oldbury Hill,  $7\frac{1}{2}$  miles E.S.E. of Warminster, and is now in the British Museum; the form of the shell, as well as its ornamentation and suture-line, agrees perfectly with *Scaphites Geinitzi*.

By some authors this species has been recorded from the Chalk Rock as *S. æqualis*—a form which is not found in the Turonian.

In the Survey Memoir on Cambridge,<sup>1</sup> *Scaphites æqualis*(?) is recorded from the zone of *Holaster planus* of Ickleton: the specimen is now in the Jermyn Street Museum, and is, I believe, referable to *S. Geinitzi*, but it is not sufficiently perfect to be determined with certainty. Whitaker<sup>2</sup> records *Scaphites* sp. from the Upper Chalk of Marlow, but the specimen has apparently been lost.

*Affinities*.—*Scaphites obliquus*, Sowerby, from the Cenomanian, is allied to the species under consideration, but differs from it in being thicker and in having the tubercles indistinct or faintly marked.

*S. æqualis*, Sowerby, from the Cenomanian, is also a thicker form, especially in the hamus, the outer border of which is less rounded than in *S. Geinitzi*, and the tubercles are costæform.

In *S. inflatus*, Römer, from the Senonian (zone of *S. binodosus*) of Westphalia, the row of tubercles is found on the involute as well as on the evolute part, and extends to the aperture. The hamus is relatively shorter than in *S. Geinitzi*, and the suture-line more divided.

In *S. hippocrepis* (Dekay) = *Cuvieri*, Morton, from the argilliferous sand of the Chesapeake and Delaware Canal, the row of tubercles is similar to that in *S. Geinitzi*, but extends to the aperture.

*Distribution*.—*England*: Chalk Rock of Dover, Winchester, Oldborough Castle, Cuckhamsley, Prince's Risborough, Boxmoor, Luton cutting, Hitchin, and Underwood Hall near Dullingham. Perhaps also in the zone of *Holaster planus* and in the Upper Chalk (? zone of *Micr. cor-testudinarium*). *France*: zone of *Epiaster brevis* at Fontaines-Vervins, zone of *Micr. breviporus* of Cambrai, zones of *Hol. planus* and *Ep. brevis* east of the Paris basin, zone of *Spondylus truncatus* of the Loir-et-Cher, and 'Craie de Villedieu.' *North-western Germany*: common in the zone of *Heteroceras Reussianum* throughout North-western Germany, rare in the zones of *Inoc. Cuvieri* and *Inoc. Brongniarti*. *Saxony*: Pläner-Kalk of Strehlen and Weinböhla, and *Scaphites*-beds of Zatzschke. *Silesia*: *Scaphites*-beds of Oppeln. *Bohemia*: through the Turonian and in the Priesen Beds; found at Priesen, Teplitz, Böhmisch-Kamnitz, Waldeck, etc. *Bavaria*: Kagerhöh Beds of the Buchleitner Bruch, near Passau.

<sup>1</sup> Penning and Jukes-Browne, 'Geol. Neighbourhood of Cambridge' (1881), p. 65.

<sup>2</sup> 'Geol. London, etc.' vol. i. (1889) p. 81.

Genus *CRIOCERAS*, Leveillé, 1836.*CRIOCERAS ELLIPTICUM* (Mantell), 1822. (Pl. III. figs. 8-10.)

1822. *Hamites ellipticus*, G. A. Mantell, 'Foss. S. Downs,' p. 122, pl. xxiii. f. 9; 1840. H. B. Geinitz, 'Charakt. d. Schichten u. Petrefacten d. sächsischen Kreidegeb.,' Heft 2, p. 41; 1841. F. A. Römer, 'Verstein. d. norddeutsch. Kreidegeb.,' p. 93, pl. xiv. f. 5; 1843. H. B. Geinitz, 'Die Verstein. von Kieslingswalda,' p. 9, pl. i. f. 7; 1846. H. B. Geinitz, 'Grundr. der Verstein.,' p. 304; 1852. C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 302; 1854. ? J. Morris, 'Cat. Brit. Foss.,' 2nd ed. p. 305.

1822. *Hamites alternatus*, G. A. Mantell, 'Foss. S. Downs,' p. 122, pl. xxiii. f. 10, 11; 1840. H. B. Geinitz, 'Charakt. d. Schichten u. Petrefacten d. sächsischen Kreidegeb.,' Heft 2, p. 41; 1841. F. A. Römer, 'Verstein. d. norddeutsch. Kreidegeb.,' p. 93.

1842. *Hamites alternans*, H. B. Geinitz, 'Charakt. d. Schichten u. Petref. d. sächsischen-böhm. Kreidegeb.,' Heft 3, p. 68, pl. xvii. f. 36; 1861. F. J. Pictet and J. Campiche, 'Foss. des Terr. Crét. de Ste.-Croix,' Pal. Suisse, ser. 3, pt. ii. p. 93.

1850. *Hamites angustus*, J. de C. Sowerby, in F. Dixon's 'Geology of Sussex,' p. 346 (p. 385 of 2nd ed. 1878), pl. xxix. f. 12; 1876. C. Barrois, 'Recherches sur le Terr. Crét. Sup. de l'Angleterre et de l'Irlande,' p. 29 (footnote 4).

1850. *Ancyloceras ellipticus*, A. d'Orbigny, 'Prodr. de Paléont.,' vol. ii. p. 147; 1861. F. J. Pictet and G. Campiche, 'Foss. du Terr. Crét. de Ste.-Croix,' Pal. Suisse, ser. 3, pt. ii. p. 41.

1850. *Hamites Geinitzii*, A. d'Orbigny, 'Prodr. de Paléont.,' vol. ii. p. 215; 1872. ? A. Fritsch and U. Schlönbach, 'Ceph. böhm. Kreideformat.,' p. 46, pl. xvi. f. 16.

1852. *Hamites armatus*, C. G. Giebel, 'Fauna der Vorwelt,' vol. iii. p. 297 (*partim*); 1854. var., J. Morris, 'Cat. Brit. Foss.,' ed. 2, p. 305.

1861. *Anisoceras alternatus*, F. J. Pictet and G. Campiche, 'Foss. des Terr. Crét. de Ste.-Croix,' Pal. Suisse, ser. 3, pt. ii. p. 71, pl. li.

1872. *Crioceras ellipticum*, C. Schlüter, 'Ceph. oberen deutsch. Kreide,' p. 100, pl. xxx. f. 11, 12, pl. xliii. f. 1, 2.

1872. ?? *Hamites cf. angustus*, C. Schlüter, *ibid.* p. 106, pl. xxxii. f. 6, 7.

1874. *Hamites ellipticum*, H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), pt. ii. p. 194, pl. xxxv. f. 13-15, ? 16.

*Description.*—Shell elliptical in section, ornamented with strong ribs, which become less prominent on the inner margin, and are slightly flexuous in the older specimens. Each rib bears a pair of tubercles, one on each side of the siphonal line; the pairs are alternately large and small, but the relative size varies in different specimens, in some the two sets are of nearly equal size, in others one set is very much smaller; occasionally the alternation in size is somewhat irregular.

*Suture-line:* siphonal lobe small, superior-lateral lobe deep, bifid, not quite symmetrical, inferior-lateral lobe similar to the last, but not so deep, internal lobe smaller, not quite symmetrical; saddles much broader than the lobes, siphonal saddle bipartite, larger than the superior-lateral saddle, inferior-lateral saddle of about the same width but not so deep as the superior-lateral.

*Remarks.*—The type of Mantell's *Hamites ellipticus* (fig. 9) is in the British Museum, but that of *Hamites alternatus* cannot be traced. Both of Mantell's specimens came from the Chalk Marl of Middleham.

*Distribution.*—*England:* Lower and Middle Chalk. Chalk Rock of Winchester, Cuckhamsley, Luton cutting, Hitchin, and Underwood Hall near Dullingham. *France:* zone of *Terebratulina gracilis* east of the Paris basin. *North-western Germany:* confined to the zone of *Het. Reussianum*, found at Heiningen, Windmühlebergen near Salzgitter, Neue Wallmoden, etc. *Saxony:* Pläner-Kalk of Strehlen and Weinböhla.

## III. Class GASTEROPODA.

## Order Prosobranchia.

## Family Fissurellidæ, Risso.

## Genus EMARGINULA, Lamarek, 1801.

## EMARGINULA SANCTÆ-CATHARINÆ, Passy.

1832. *Emarginula Sanctæ-Catharinæ*, A. Passy, 'Descr. Géol. de la Seine-Inférieure,' p. 335, pl. xvi. f. 1; 1843. A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. ii. p. 395, pl. ccxxxv. f. 4-6; 1877. J. S. Gardner, Quart. Journ. Geol. Soc. vol. xxxiii. p. 198, pl. viii. f. 21, 22.

1850. *Emarginula affinis*, J. de C. Sowerby, in F. Dixon's 'Geol. Sussex,' p. 348 (p. 383 of ed. 2), pl. xxvii. f. 20, 25; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 246; 1877. J. S. Gardner, Quart. Journ. Geol. Soc. vol. xxxiii. p. 200.

*Affinities*.—This is a species with cancellated ornament produced by longitudinal ribs of two sizes crossed by transverse ribs. It is distinguished from *E. uncostata*, Gardner (Upper Chalk of Norwich), by its more elevated form; from *E. loculata*, de Ryckholt (Cenomanian of Tournay and Montignies-sur-Roc), by possessing ribs of two sizes; and from *E. Desori*, Pictet and Campiche (Upper Gault of Ste.-Croix), by having more numerous ribs.

*Remarks*.—The specimens from the Chalk Rock agree in every respect with Sowerby's *E. affinis*, and this, as suggested by Mr. Gardner, is, I think, without doubt identical with *E. Sanctæ-Catharinæ*.

The figure given by Passy is very unsatisfactory, and is not accompanied by a description of any kind, so that one is almost obliged to rely on d'Orbigny's figures and diagnosis. The type comes from the Cenomanian of Rouen.

I have not been able to find Sowerby's type; the specimen figured by Gardner, which comes from the Chloritic Marl of White Nore, is in the Museum of Practical Geology, No.  $\frac{50}{103}$ .

*Localities*.—*England*: Chloritic Marl of Wiltshire and Dorset; Lower Chalk of Kent and Sussex; Chalk Rock of Cuckhamsley and Luton cutting. *France*: Cenomanian of Rouen.

## EMARGINULA aff. DIVISIENSIS, Gardner.

1877. *E. divisiensis*, J. S. Gardner, Quart. Journ. Geol. Soc. vol. xxxiii. p. 198, pl. viii. f. 19, 20.

A cast from Cuckhamsley in the Montagu Smith collection is allied to this species, but is hardly sufficiently well-preserved for definite determination; it is more ovate than *E. divisiensis*. The type of *E. divisiensis* comes from the Upper Greensand of Devizes, and is preserved in the British Museum.

## EMARGINULA sp.

A single specimen from the Chalk Rock of Cuckhamsley is apparently new. It has a subcircular form, with a much elevated and nearly central apex; it is in the form of a cast, and the ornamentation is unknown.

## Family Pleurotomariidæ, d'Orbigny.

## Genus PLEUROTOMARIA, DeFrance, 1821.

## Sub-genus LEPTOMARIA, Eudes-Deslongchamps, 1865.

## PLEUROTOMARIA (LEPTOMARIA) PERSPECTIVA (Mantell). (Pl. III. figs. 13, 14, &amp; Pl. IV. fig. 1.)

1822. *Cirrus perspectivus*, G. A. Mantell, 'Foss. S. Downs,' p. 194, pl. xviii. f. 12, 21; 1823. J. Sowerby, 'Min. Conch.' vol. v. p. 35, pl. ccccxviii. f. 1, 2.

1822. *Trochus linearis*, Mantell, *ibid.* p. 110, pl. xviii. f. 16, 17.

1822. *Cirrus depressus*, Mantell, *ibid.* p. 195, pl. xviii. f. 18, 22; 1823. Sowerby, 'Min. Conch.' vol. v. p. 35, pl. ccccxviii. f. 3.

1835. *Pleurotomaria distincta*?, F. Dujardin, Mém. Soc. géol. de France, vol. ii. p. 231, pl. xvii. f. 6; 1840. A. Goldfuss, 'Petref. Germ.' pt. 3, p. 75, pl. clxxxvii. f. 1; 1841. F. A. Römer, 'Die Verstein. des norddeutsch. Kreidegeb.' p. 82 (*partim*).

1840. *Trochus linearis*, H. B. Geinitz, 'Char. d. Schicht. u. Petref. des sächs. Kreidegeb.' Heft 2, p. 46, pl. xiii. f. 6, 8, pl. xv. f. 18, 19.

1840. *Pleurotomaria velata*, A. Goldfuss, 'Petref. Germ.' p. 76, pl. clxxxvii. f. 2.

1840. *Pleurotomaria granulifera*, Goldfuss, *ibid.* p. 76, pl. clxxxvii. f. 3.

1842. *Pleurotomaria perspectiva*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. ii. p. 255, pl. cxvii. f. 1-5; 1850. J. de C. Sowerby, in F. Dixon's 'Geol. Sussex,' p. 349 (p. 384, ed. 2), pl. xxvii. f. 27; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 271; 1863. F. J. Pictet & G. Campiche, 'Foss. Terr. Crét. Ste.-Croix,' ser. 3, pt. ii, Pal. Suisse, p. 454; 1874. H. B. Geinitz, 'Das Elbthalgeb. in Sachsen' (Palaeontographica, vol. xx.), part ii. p. 166 (? pl. xxix. f. 11); 1889. A. Fritsch, 'Stud. im Geb. der böhm.-Kreidegeb. IV. Die Teplitzer Schichten,' p. 74, f. 49.

1845. *Pleurotomaria linearis*, A. E. Reuss, 'Die Verstein. böhm. Kreideformat.' p. 47; 1850. H. B. Geinitz, 'Das Quadersandst. oder Kreidegeb. in Deutschland,' p. 134 (*partim*); 1870. F. A. Römer, 'Geol. von Oberschlesien,' p. 318, pl. xxxv. f. 1, 2; 1874. H. B. Geinitz, 'Das Elbthalgeb. in Sachsen' (Palaeontographica, vol. xx.), pt. ii. p. 165, pl. xxix. f. 10; 1883. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. III. Die Iserschichten,' p. 95, f. 57; 1889. Fritsch, *ibid.* 'IV. Die Teplitzer Schichten,' p. 74, f. 48.

1846. *Pleurotomaria (Trochus) linearis*, H. B. Geinitz, 'Grundriss der Verstein.' p. 355, pl. xv. f. 1.

*Description.*—Shell heliciform, depressed, composed of 7 whorls, which are obtusely angular, the parts above and below the angle being flat or nearly flat. Base of last whorl rounded. Sinus-band narrow, prominent, smooth (apparently), placed at the angle, slightly posterior to the middle of the whorl. Umbilicus large, deep. Sutures shallow. Ornamentation consisting of numerous longitudinal ribs, which, on the earlier whorls, are markedly granular, the granules having a transverse arrangement also. Growth-lines curving backwards to the sinus-band are seen on some of the later whorls. Base with numerous close-set longitudinal (spiral) ribs. Aperture broad, outer lip rounded. Size of a large specimen: length 44 mm., width 82 mm.

*Remarks.*—The appearance of this species varies considerably, according to the state of preservation and the age of the specimens. The granular character of the ornamentation is seen best in young individuals; on the later whorls of large specimens the ribs are often nearly smooth, but this is probably due to abrasion. When the shell is much worn, the surface appears to be striated rather than ribbed. The sides of the spire are convex, except in young



forms, in which, in the apical part at any rate, they are flat or concave.

*P. perspectiva* is almost the only gasteropod of the Chalk Rock in which the shell is generally preserved. It is also one of the commonest species; in the Woodwardian Museum there are no less than 65 specimens from a single locality—namely, Cuckhamsley.

Mantell does not give any exact locality for his *Cirrus perspectivus*, but simply states 'Upper and Lower Chalk of the South Downs: rare in the latter deposit.' The forms described by Mantell as *Trochus linearis* (from the Chalk Marl of Hamsey) and *Cirrus depressus* (from the Upper Chalk of Lewes) have been considered by d'Orbigny, Morris, and others to be identical with *perspectivus*: the apparent differences being due merely to conditions of preservation. The examination of a large series of specimens which I have made confirms this view. Geinitz and Fritsch, however, regard *P. perspectiva* and *P. linearis* as distinct species.

The types of Mantell's *Cirrus perspectivus* (except fig. 12), *C. depressus*, and *Trochus linearis* are preserved in the British Museum; so also are the originals of Sowerby's figures of *Cirrus perspectivus* and *C. depressus*, and of Dixon's figure of *P. perspectiva*. Both Mantell's and Sowerby's specimens are badly preserved, and hence it is very difficult to make out the real characters of the species.

*Affinities.*—*P. neocomiensis* of d'Orbigny, from the Lower Cretaceous of France, is distinguished from *P. perspectiva* by the smaller spiral angle, the ornamentation consisting of striæ instead of ribs, and by the sinus-band being sunk.

The absence of longitudinal ribs and the presence of strong growth-lines on the base of the shell separate *P. plauensis*, Geinitz (Cenomanian of Plauen, etc.), from this species.

*P. seriato-granulata*, Goldfuss, from the Turonian of Saxony and Bohemia, is near to *P. perspectiva*, but the shell is more depressed and the base of the whorl is angular.

Barrois's *P. Merceyi*,<sup>1</sup> from the zone of *Micr. cor-anguinum* of Lezennes, etc., is related to *P. perspectiva*, but the figure given by that author is not sufficiently clear to allow of any detailed comparison being made.

*Distribution.*—*England*: Chalk Marl of Folkestone and Hamsey; Lower Chalk of the Isle of Wight; Upper Chalk of Norwich, Northfleet, and Lewes. Chalk Rock of Dover, Winchester, Old-borough Castle, Cuckhamsley, Aston Rowant, Prince's Risborough, Luton, Hitchin, Underwood Hall near Dullingham, and Carleton Grange. *Ireland*: Hibernian Greensand. *France*: Cenomanian of Rouen. *Westphalia*: Senonian of Haldem, Coesfeld, and Lemförde. *Saxony*: Pläner-Kalk of Strehlen and Weinböhla, rarely in older beds. *Silesia*: *Scaphites*-beds of Oppeln. *Bohemia*: Iser, Teplitz, and Priesen Beds. *Bavaria*: Regensburg Beds of Galgenburg, Reinhausen, etc.

<sup>1</sup> Ann. Soc. géol. du Nord, vol. vi. (1879) p. 450, pl. xii. f. 2 a, b.

## Family Trochidæ, Adams.

Genus TROCHUS, Linnæus, 1758.

TROCHUS SCHLÜTERI, sp. nov. (Pl. III. figs. 11 &amp; 12.)

*Description*.—Shell conical, without an umbilicus. Whorls flat, six (or seven) in number, with a deep depression at the suture: surface ornamented with fine longitudinal rows of tubercles, the marginal rows being a little larger than the three inner rows. Tubercles connected by faintly-marked longitudinal and transverse ribs, the latter crossing the whorls obliquely and parallel to the margin of the aperture. In the sutural depression just above the middle is a row of smaller tubercles. The spire is about  $\frac{4}{5}$ ths the entire length of the shell. Base a little convex, with eight or nine longitudinal (spiral) ribs bearing close-set tubercles. Aperture not well seen.

*Affinities*.—The ornamentation of this species is very similar to that in *T. amatus*, d'Orbigny<sup>1</sup> (from Haldem, Strehlen, etc.), but in that form the whorls are rounded.

*Distribution*.—Chalk Rock of Dover, Oldborough Castle, Cuckhamsley, Luton cutting, Hitchin, Reed near Royston, and Underwood Hall near Dullingham.

TROCHUS BEROSCIRENSE, sp. nov. (Pl. IV. figs. 2–4.)

*Description*.—Shell conical, composed of six flat whorls, spiral angle  $58^{\circ}$ ; spire about  $\frac{3}{5}$ ths the entire length; sutures deep. Whorls ornamented with fine longitudinal rows of tubercles, the top and two bottom rows being much larger than the others. Base a little convex, with a depression at the centre; ornamented with curved growth-lines and a row of small tubercles near the periphery. Aperture sub-rhomboidal.

*Affinities*.—This species resembles *T. Engelhardti*, Geinitz,<sup>2</sup> from the Pläner-Kalk of Strehlen; but in that form the sutures are not so deep, and the ornamentation consists of a row of large tubercles at the top and at the bottom of each whorl, with three or four smaller rows between.

*Remarks*.—I have only seen five specimens of this species, all of which are in the Montagu Smith Collection.

*Distribution*.—Chalk Rock of Cuckhamsley.

## Family Turbinidæ, Chenu.

Genus TURBO, Linnæus, 1758.

TURBO GEINITZI, sp. nov. (Pl. IV. figs. 5–8.)

*Description*.—Shell turbinate, turrated, sutures deep, spiral angle

<sup>1</sup> 'Prodr. de Pal.' vol. ii. (1850) p. 224. For figure see Goldfuss, 'Petref. Deutschl.' pt. iii. (1840) p. 58, pl. clxxxi. f. 7, and Geinitz, 'Das Elbthalgeb. in Sachsen' (Palaeontographica, vol. xx.), pt. ii. (1874) p. 164, pl. xxix. f. 7.

<sup>2</sup> 'Das Elbthalgeb. in Sachsen' (Palaeontographica, vol. xx.), pt. ii. (1874) p. 163, pl. xxix. f. 5.

about 39°. Whorls 4 or 5 in number, convex, rather angular, the posterior part of each is flat and ornamented with four longitudinal rows of tubercles; at the keel is a row of large and prominent tubercles, anterior to which is a nearly flat band with faint ribbing, and then three or four more longitudinal rows of tubercles. Base convex, rounded, with numerous close-set longitudinal (spiral) ribs bearing small tubercles. Umbilicus of moderate size. Aperture sub-circular.

*Affinities.*—The general form of the shell is similar to fig. 5 of Römer's<sup>1</sup> *Delphinula tricarinata*, but in that species there is apparently only one row of tubercles; the other specimens figured by the same author (figs. 3, 4, and 6) are quite unlike our species.

Portlock<sup>2</sup> in 1843 gave under the name of *Turbo? bicarinatus* [Sowerby MS.] a brief description, without figures, of a very imperfect specimen from the White Limestone of Tamlaght, co. Derry, which is probably allied to *T. Geinitzi*. The name, however, was already occupied, and was changed by Tate<sup>3</sup> in 1865 to *Thomsoni*, he at the same time referring it to the genus *Pleurotomaria*. The type is preserved in the Museum of Practical Geology, Jermyn Street, no.  $\frac{53}{66}$ . It consists of three whorls; over a considerable part of the specimen the inner layer only of the shell is present; this gives some idea of the original form of the whorls, justifying Portlock's statement that they have 'two slight parallel, rather distant ridges winding up below their middle.' Adjoining the suture of the last preserved whorl is a very small fragment of the outer layer of the shell showing the ornamentation: this is much less coarse than in the Chalk Rock species. I have not been able to obtain another specimen from the White Limestone; and until this is done the characters of the Irish species and its relation to *T. Geinitzi* cannot be made out.

*Distribution.*—Chalk Rock of Dover, Cuckhamsley, Hitchin, and Luton.

#### TURBO GEMMATUS, Sowerby. (Pl. IV. figs. 9 & 10.)

1850. *Turbo gemmatus*, J. de C. Sowerby, in F. Dixon's 'Geol. Sussex,' p. 349 (p. 385, ed. 2, 1878), pl. xxvii. f. 26, 33; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 283.

1878. *Turbo Heberti*, C. Barrois and J. de Guerne, Ann. Soc. géol. du Nord, vol. v. p. 58, pl. iii. f. 11; 1887. A. Peron, 'Notes pour servir à l'Hist. du Terr. de Craie,' Bull. Soc. Sci. hist. et nat. de l'Yonne, ser. 3, vol. xii. p. 142, pl. i. f. 5-8.

[*Non T. gemmatus*, Lycett, Quart. Journ. Geol. Soc. vol. xiv. (1853) p. 342, pl. xiv. f. 7, from the Inferior Oolite.]

*Description.*—Shell conical, slightly longer than broad, composed of six whorls which are a little convex, and ornamented with several (generally seven) longitudinal ribs bearing granules—those on the upper rib being larger than the others. Sutures well marked. Margin of the last whorl rounded; base slightly convex; umbilicus large with a ridged margin. Aperture subquadrangular or rounded.

<sup>1</sup> F. A. Römer, 'Die Verstein. des norddeusch. Kreidegeb.' 1841, p. 81, pl. xii. f. 3-6.

<sup>2</sup> 'Report on the Geology of Londonderry, etc.' p. 421.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xxi. p. 37.

*Remarks.*—Sowerby's types, which come from the Lower Chalk of Kent, are in the British Museum. Barrois states that *T. Heberti* differs from *T. gemmatus* by the ridges on the margin of the umbilicus, but in the specimens figured by Sowerby the umbilicus cannot be seen; in examples from the Chalk Rock, however, the ridges are present, so that there seems to be no reason for separating *T. Heberti* from the English species.

*T. Guerangeri*, d'Orbigny, can be distinguished from this species by the more angular whorls, whilst in *T. Goupilianus* of the same author the whorls are much more convex.

*Distribution.*—*England*: Lower Chalk of Kent and Sussex (*vide* Morris and Dixon). Chalk Rock of Dover, Winchester, Oldborough Castle, Cuckhamsley, Luton cutting, Hitchin, Reed near Royston, Barkway, and Underwood Hall near Dullingham. *Northern France*: Cenomanian of Ste. Parres-aux-Tertres, near Troyes, and Vitry-le-François; zone of *Bel. plenus* at Neuville-au-Pont, Charontelles (Marne), etc.; Turonian of Villecien, near Joigny (Yonne).

#### TURBO GEMMATUS, var. *α*.

There are several specimens in the Montagu Smith Collection which agree with *T. gemmatus*, except in being much longer; the shell is almost twice as long as broad and consists of 9 whorls. It will, I think, be best to regard this form simply as a variety of *T. gemmatus*.

*Distribution.*—Chalk Rock of Cuckhamsley.

### Family Capulidæ, Fleming.

#### Genus CREPIDULA, Lamarck, 1799.

##### CREPIDULA, sp.

*Remarks.*—Some specimens of a *Crepidula* closely resemble *C. Cooksoniæ*, Seeley,<sup>1</sup> from the Cambridge Greensand (= *Calyptræa Sanctæ-Crucis*, Pictet and Campiche, from the Upper Gault of Ste.-Croix), except that the internal plate is relatively smaller. There is a good deal of variation in the form of the shell, some examples being much elevated, others depressed; in the former the cast of the septum has the appearance of an inverted U, but in the latter the limbs of the U diverge widely.

All the specimens are in the form of internal casts, and consequently I refrain from giving a specific name.

*Distribution.*—Chalk Rock of Cuckhamsley (Montagu Smith Collection).

<sup>1</sup> H. G. Seeley, Ann. Mag. Nat. Hist. ser. 3, vol. vii. (1861) p. 291, pl. xi. f. 18. See also A. J. Jukes-Browne, Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 294; J. S. Gardner, *ibid.* vol. xxxiii. (1877) p. 201, and Geol. Mag. 1877, pl. xvi. f. 19, p. 556. For *C. Sanctæ-Crucis*, see Pictet and Campiche, 'Foss. du Terr. Crét. de Ste.-Croix,' 1864, p. 696, pl. xcvi. figs. 5-8. Mr. Gardner considers that these species, and perhaps also *Galericulus altus*, Seeley, are identical with *Crepidula gaultina*, Buvignier.

## Family Naticidæ, Guilding.

Genus NATICA, Adanson, 1757.

NATICA (NATICINA<sup>1</sup>) VULGARIS, REUSS.

1840. *Littorina rotundata*, H. B. Geinitz (*non* Sowerby sp.), 'Char. der Schichten und Petrefacten des sächs. Kreidegeb.' Heft 2, p. 45, pl. xiii. f. 7, pl. xv. f. 16 (p. pl. xiv. f. 10, pl. xv. f. 17).

1844. *Natica vulgaris*, A. E. Reuss, 'Die Kreidegeb. des westlichen Böhmens,' vol. ii. p. 209; p. 1843. H. B. Geinitz, 'Die Verstein. von Kieslingswalda,' p. 10, pl. i. f. 21 (*non* figs. 22-23); 1845. A. E. Reuss, 'Die Verstein. der böhm. Kreideformat.' p. 50, pl. x. f. 22; 1846. H. B. Geinitz, 'Grundriss der Verstein.' p. 339, pl. xv. f. 18; 1850. *id.* 'Das Quadersandst. oder Kreidegeb. in Deutschland,' p. 128 (*partim*); 1889. A. Fritsch, 'Stud. im Geb. der böhm. Kreidef. IV. Die Teplitzer Schichten,' p. 73; 1893. Fritsch, *ibid.* 'V. Die Priesener Schichten,' p. 82, fig. 67.

1875. *Natica lamellosa*, H. B. Geinitz, 'Das Elbthalgebirge in Sachsen' (Palaeontographica, vol. xx.), pt. i. p. 243, pl. liv. f. 17; 1877. A. Fritsch, 'Stud. im Gebiete der böhm. Kreideformat. II. Die Weissenberger und Malnitzer Schichten,' p. 105, woodcut 43; 1883. Fritsch, *ibid.* 'III. Die Iserschichten,' p. 94.

*Description*.—Shell a little longer than wide. Spire more than half the last whorl in length. Whorls 5, rounded and very convex, especially the last. Surface with lines of growth and also distant faintly-marked rings (varices); the lines of growth are crossed by fine longitudinal striae. Umbilicus rather small. Aperture elongate-oval.

*Affinities*.—Geinitz considers this species to be identical with *N. lamellosa*, of Römer,<sup>2</sup> from Kieslingswalda; but Fritsch apparently regards it as distinct. This, however, is a point which can hardly be settled by the aid of Römer's figure.

*N. cretacea*, Goldfuss,<sup>3</sup> from the Aachen Greensand, differs from *N. vulgaris* in having a much wider aperture.

*N. exaltata*, Goldfuss,<sup>4</sup> also from the Aachen Greensand, is distinguished by the greater length of the shell.

*N. lyrata*, Sowerby,<sup>5</sup> from Gosau, is allied to *N. vulgaris*, but possesses a shorter spire.

Stoliczka<sup>6</sup> considers that *Euspira pagoda* (Forbes), from the Arrialoor Group, is closely related to this species, but the whorls in that form are more numerous and the spire more acute.

*Remarks*.—I have seen 23 examples of this species from the Chalk Rock, but most of them are in the condition of casts; a few show portions of the shell with the lines of growth and longitudinal striae. The varices are indicated on the casts by slight depressions.

The type figured by Reuss came from the Pläner-Mergel of Priesen, Bohemia.

<sup>1</sup> *Naticina* of Guilding, 1834.

<sup>2</sup> 'Die Verstein. des norddeutsch. Kreidegeb.' (1841) p. 83, pl. xii. f. 13.

<sup>3</sup> 'Petref. Germ.' (1840) p. 119, pl. cxcix. f. 12. See also Binkhorst, 'Mon. des Gast. et Céph. de la Craie Supér. du Limbourg' (1861), p. 21.

<sup>4</sup> *Ibid.* (1840) p. 111, pl. cxcix. f. 12.

<sup>5</sup> Sowerby, Trans. Geol. Soc. ser. 2, vol. iii. (1835) pl. xxxviii. f. 11. See also d'Orbigny, 'Terr. Crét.' vol. ii. (1842) p. 161, pl. clxxii. f. 5; Zekeli, 'Die Gastr. d. Gosaugeb.' Abh. d. k. k. geol. Reichsanst. vol. i. (1852) p. 46, pl. viii. f. 5; and Stoliczka, 'Cret. Fauna S. India,' vol. ii. (1868) p. 303, pl. xxii. f. 2 (Palaeont. Indica).

<sup>6</sup> *Op. cit.* p. 301.

*Distribution*.—*England*: Chalk Rock of Cuckhamsley, and Underwood Hall near Dullingham; *Saxony*: Pläner-Kalk of Strehlen, Pläner-Mergel of Walkmühle near Pirna, etc.; *Bohemia*: throughout the Turonian and in the Priesen and Korycan Beds of numerous localities; *Bavaria*: Grossberg Beds.

### Family Cerithiidae (Férussac), Menke.

#### Genus CERITHIUM, Adanson, 1757.

##### CERITHIUM CUCKHAMSLIENSE, sp. nov. (Pl. IV. fig. 11.)

*Description*.—Shell elongate, composed of about twelve whorls. Spiral angle  $21^{\circ}$ . Whorls flat or very slightly convex, with a narrow anterior part sloping steeply to the suture; surface smooth or with growth-lines. Aperture imperfectly known. Length (approximative) 38 mm., width 14 mm.

*Affinities*.—This species resembles *C. excavatum* of Brongniart,<sup>1</sup> from the Gault, but in that form the whorls are more concave, and the sutures are bordered by two ridges.

*Distribution*.—Chalk Rock of Cuckhamsley and Luton.

##### CERITHIUM SAUNDERSI, sp. nov. (Pl. IV. fig. 12.)

*Description*.—Shell elongate, turritid, composed of twelve whorls. Spiral angle  $18^{\circ}$ – $19^{\circ}$ . Whorls nearly flat; sutures fairly distinct. Ornamentation consists of round tubercles having a transverse and longitudinal arrangement; there are four longitudinal rows of equal size, and about sixteen transverse rows on each whorl. The longitudinal rows are separated by less than the diameter of a tubercle; the transverse are more distant. Between the longitudinal rows there are three or four fine ribs. Immediately posterior to the suture is a fifth row of smaller and more numerous tubercles. Base with spiral striæ. Aperture not well seen. Length (approximative) 37 mm., width 11 mm.

*Affinities*.—This species is easily distinguished from *C. pustulosum*, Sowerby<sup>2</sup> (Gosau Beds), by its smaller spiral angle and fewer tubercles. *C. pustulosum* of d'Orbigny<sup>3</sup> (*non* Sowerby) is near to *C. Saundersi*, but the sutures are much deeper.

*C. pseudoclathratum*, d'Orbigny,<sup>4</sup> differs from this by its greater sutural angle, and by the posterior rows of tubercles being smaller than the anterior.

*Distribution*.—Chalk Rock of Cuckhamsley and Hitchin.

<sup>1</sup> 'Envir. de Paris,' in Cuvier's 'Oss. Foss.' vol. ii. (1822) p. 614, pl. ix. f. 10; d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. ii. (1843) p. 371, pl. cccxx. f. 12; Pietet and Roux, 'Moll. Foss. d. Grès Verts des Env. de Genève' (1849), p. 279, pl. xxvii. f. 7 a-c.

<sup>2</sup> Sowerby, Trans. Geol. Soc. ser. 2, vol. iii. (1835) pl. xxxix. f. 19. See also Zekeli, 'Die Gasterop. d. Gosaugeb.' Abh. der k. k. geol. Reichsanst. vol. i. (1852) p. 100, pl. xix. f. 4, 5.

<sup>3</sup> 'Paléont. Franç. Terr. Crét.' vol. ii. (1843) p. 381, pl. cccxxiii. f. 4.

<sup>4</sup> Geinitz, 'Das Elbthalgeb. in Sachsen' (Palaeontographica, vol. xx.), pt. ii. (1874) p. 175, pl. xxxi. f. 5.

## Family Aporrhaidæ, Philippi.

Genus APORRHAI, Da Costa, 1778.

Subgenus LISPODESTHES, White, 1875.

APORRHAI (LISPODESTHES) MANTELLI, Gardner.

1822. *Rostellaria Parkinsoni*, G. A. Mantell, 'Foss. S. Downs,' p. 108, pl. xviii. f. 1, 2, 4-6, 10.1850. *Aporrhais stenopterus*, F. Dixon, 'Geol. Sussex,' p. 353 (p. 386, ed. 2), pl. xxvii. f. 31, 36; 1854. J. Morris, 'Cat. Brit. Foss.' ed. 2, p. 235.1867. *Aporrhais (Perissoptera) Parkinsoni*, R. Tate, 'Geol. & Nat. Hist. Repert.' vol. i. p. 99.1875. *Aporrhais Mantelli*, J. S. Gardner, Geol. Mag. dec. 2, vol. ii. p. 202, pl. vi. f. 8, 9.

*Remarks.*—The originals of Mantell's figures 1, 5, 6, and 10 are in the British Museum. The specimens from the Chalk Rock are in the form of casts only.

*Distribution.*—Grey Chalk of Dover, Chalk Marl of Hamsey. Chalk Rock of Cuckhamsley, and Luton cutting.

APORRHAI, sp.

Another species occurs in the Chalk Rock of Cuckhamsley (Montagu Smith Collection), but is not sufficiently well represented for determination. The spiral angle is about 20°. The whorls are angular and provided with an almost median keel; midway between this and the anterior suture is a rib. No other ornamentation is visible.

## Family Lampusidæ, Newton.

Genus LAMPUSIA, Schumacher, 1817.

LAMPUSIA?, sp. (Pl. IV. figs. 13, 14.)

There are five specimens in the Montagu Smith Collection which apparently belong to this genus—three are internal casts, one is an external cast, and one has a small portion of the shell preserved. The shell consists of five or six rather convex whorls, each with about twelve prominent transverse ridges, and with numerous longitudinal ribs of two sizes. The casts show the crenulation of the outer lip. Spiral angle about 30°.

## Order Opisthobranchia.

## Family Ringiculidæ, Meek.

Genus AVELLANA, d'Orbigny, 1842 (*sensu stricto*).

AVELLANA, sp., cf. HUMBOLDTI, Müller. (Pl. IV. fig. 15.)

1851. *Avellana Humboldti*, J. Müller, 'Mon. der Petref. der Aachener Kreideformat.' part ii. p. 12, pl. iii. f. 15.1888. *Cinulia Humboldti*, E. Holzapfel, 'Die Mollusken der Aachener Kreide' (Palaeontographica, vol. xxxiv.), p. 84, pl. vi. f. 19-21.

*Description.*—Shell globose, a little longer than broad, composed

V. TABLES SHOWING THE DISTRIBUTION OF THE CEPHALOPODA, GASTEROPODA, AND SCAPHOPODA FOUND IN THE CHALK ROCK.

Genus and Species.	Author.	
<i>Nautilus sublevigatus</i> .....	d'Orbigny	?
<i>Ptychoceras Snüthi</i> .....	sp. nov.	?
<i>Hamites</i> , sp. ....	d'Orbigny	?
<i>Heteroceras Reussianum</i> .....	sp.	?
<i>Baculites bohemicus</i> .....	Fritsch.	?
<i>Prionocyclus Neptuni</i> .....	(Geinitz)	?
<i>Pachydiscus peramplus</i> .....	(Mantell)	?
<i>Scaphites Geinitzi</i> .....	d'Orbigny	?
<i>Croceras ellipticum</i> .....	(Mantell)	?
Lower Chalk.	*	*
Zone of <i>Rhynchonella Cuvieri</i> .	?	*
Zone of <i>Terebratulina gracilis</i> .	?	*
Zone of <i>Holaster planus</i> .	?	*
Dover.	?	*
Winchester.	?	*
Cuckhamsey.	?	*
Aston Rowant.	?	*
Luton cutting.	?	*
Hitchin.	?	*
Cambridgeshire.	?	*
Upper Chalk.	?	*
Hibernian Greensand.	?	*
White Limestone.	?	*
Cenomanian.	?	*
Zone of <i>Inoceramus labiatus</i> .	?	*
Zone of <i>Terebratulina gracilis</i> .	?	*
Zone of <i>Micraster breviporus</i> .	?	*
Higher Beds.	?	*
Zone of <i>Inoceramus Brongniarti</i> .	?	*
Zone of <i>Heteroceras Reussianum</i> .	?	*
Zone of <i>Inoceramus Cuvieri</i> .	?	*
Beds with <i>Inoc. labiatus</i> .	?	*
Beds with <i>Inoc. Brongniarti</i> .	?	*
Beds with <i>Scaphites Geinitzi</i> .	?	*
<i>Scaphites</i> -beds.	?	*
Wassenberg Beds.	*	*
Malnitz Beds.	*	*
Tepitz Beds.	*	*
Priesen Beds.	*	*
Kagerhoh Beds.	*	*
Gosau Beds.	?	?
Gosau, etc.		
Bohemia.		
Silesia.		
Saxony.		
TURO- NIAN.		
North-western Germany.		
Northern France.		
North of Ire- land.		
England.		
CHALK ROCK, or Reussianum-zone.		



[illegible]

of four or five whorls; outer lip thickened, with the inner margin coarsely crenulated. Columella with two or three strong folds. Ornamentation consisting of fine spiral grooves (about 24 on the last whorl) with pits in the grooves. Size of an average specimen—height 18 mm., height of last whorl 16 mm., diameter 14 mm.

*Remarks.*—*A. Archiaciana* is found in the Aachen Greensand; the Chalk Rock species is very near to this, but without seeing specimens of the Aachen form I cannot be quite sure of their identity. Most of the specimens from the Chalk Rock are in the form of casts, but a few have part of the shell preserved; the character of the ornamentation is seen in the wax models taken from the external casts.

*Distribution.*—Chalk Rock of Winchester, Cuckhamsley, Luton cutting, Hitchin, and Underwood Hall near Dullingham.

In addition to the species described above there are a few others which are too imperfect for determination.<sup>1</sup> The most interesting of these is one which belongs to the Volutidæ or Mitridæ; it is represented by four imperfect casts from Cuckhamsley (Montagu Smith Collection) and one from Hitchin (coll. Mr. W. Hill). There are three well-marked folds on the columella; the spire of the shell was long. Length of the two last whorls 27 mm., width 10 mm.

#### IV. Class SCAPHOPODA.

##### Family Dentaliidae, Gray.

##### Genus DENTALIUM, Linnæus, 1758.

##### DENTALIUM TURONIENSE, sp. nov. (Pl. IV. figs. 16 & 17.)

*Description.*—Shell slender, elongate, tapering very gradually, circular in section. Ornamentation consisting of twenty-five to twenty-eight straight longitudinal ribs, crossed by smaller transverse ribs. Length about 47 mm.

*Affinities.*—*D. planicostatum*, Hébert,<sup>2</sup> from Meudon, is similar to this species, but is distinguished by the absence of transverse ribs and by the more rapid tapering of the shell.

*Distribution.*—Chalk Rock of Winchester, Cuckhamsley, and Luton cutting.

<sup>1</sup> *Solarium* has been recorded from the Chalk Rock, but I have seen no example of this genus; the determinations were probably based on the internal casts of *Pleurotomaria*.

<sup>2</sup> Mém. Soc. géol. France, ser. 2, vol. v. (1855) p. 374, pl. xxix. f. 11.

## EXPLANATION OF PLATES II.-IV.

[All specimens from the Chalk Rock.]

## PLATE II.

- Figs. 1, 2. *Ptychoceras Smithi*, sp. nov. Cuckhamsley. Montagu Smith Collection, Woodwardian Museum. 1.  $\times 3$ . 2. Suture-line,  $\times$  about 6.
- 3-5. *Heteroceras Reussianum* (d'Orbigny). 3. Portion of one of the later whorls. Luton cutting. Coll. Dr. Morison. Nat. size.
- 3a. Section of whorl of the same.
4. Base of later whorl. Cuckhamsley. Montagu Smith Collection. Nat. size.
5. Suture-line of a specimen in the collection of Dr. Morison. Luton cutting.  $\times 4$ .
- 6-8. *Heteroceras*, sp. 6. Luton cutting. Coll. Dr. Morison. Nat. size.
- 7a, b, c. Cuckhamsley. Montagu Smith Collection. Nat. size.
8. Suture-line of specimen, fig. 7.  $\times 4$ .
- 9-10. *Baculites bohemicus*, Fritsch and Schlönbach. Cuckhamsley. Montagu Smith Collection. 9a, siphonal side; 9b, lateral; 9c, lateral; 9d, section, nat. size. 10. Suture-line,  $\times 4$ .
11. *Prionocyclus Neptuni* (Geinitz). Suture-line. Dunstable. Museum of Practical Geology, Jermyn Street. Enlarged.

## PLATE III.

- Figs. 1-4. *Prionocyclus Neptuni* (Geinitz). 1. Portion of last whorl. Cuckhamsley. Montagu Smith Collection. Nat. size.
2. Dunstable. Museum of Practical Geology. Nat. size.
- 3, 3a. Cuckhamsley. Montagu Smith Collection. Nat. size.
4. Section of whorl. Luton cutting. Coll. Dr. Morison. Nat. size.
- 5-7. *Scaphites Geinitzi* (d'Orbigny). Cuckhamsley. Montagu Smith Collection. 5, 5a, small specimen with projecting lip, nat. size; 6, 6a, medium-size specimen, nat. size; 7, suture-line,  $\times 5$ .
- 8-10. *Crioceras ellipticum* (Mantell). 8. Cuckhamsley, Montagu Smith Collection; 8a. Section, nat. size. 9. Luton cutting, coll. Dr. Morison, nat. size; 9a. Section. 10. Suture-line, Luton cutting, Museum of Practical Geology (J. R. 2270),  $\times 3$ .
- 11, 12. *Trochus Schliiteri*, sp. nov. Cuckhamsley. Montagu Smith Collection. 11. Drawn from a wax mould,  $\times 1\frac{1}{2}$ . 12. Base of an imperfect specimen,  $\times 1\frac{1}{2}$ .
- 13, 14. *Pleurotomaria (Leptomaria) perspectiva*, Mantell. Cuckhamsley. Montagu Smith Collection. 13. Portion of a whorl seen from above,  $\times 2$ . 14. Base of a small specimen, nat. size.

## PLATE IV.

- Fig. 1. *Pleurotomaria (Leptomaria) perspectiva*, Mantell. Cuckhamsley. Montagu Smith Collection. The largest specimen seen in the Chalk Rock. Nat. size.
- 2-4. *Trochus berocscirensis*, sp. nov. Cuckhamsley. Montagu Smith Collection. 2. Drawn from a wax mould,  $\times 1\frac{1}{2}$ . 3. Outline of a specimen, nat. size. 4. Base of a specimen,  $\times 1\frac{1}{2}$ .
- 5-8. *Turbo Geinitzi*, sp. nov. Cuckhamsley. Montagu Smith Collection. 5. Nat. size; the ornamentation is taken from a wax mould. 6. Specimen showing aperture, nat. size. 7. Base, nat. size. 8. Ornamentation of base,  $\times 2\frac{1}{2}$ .
- 9, 10. *Turbo gemmatus*, Sowerby. Cuckhamsley. Montagu Smith Collection. 9,  $\times 2$ ; 10,  $\times 1\frac{1}{2}$ .
11. *Cerithium cuckhamsiense*, sp. nov. Cuckhamsley. Montagu Smith Collection. Nat. size.

- Fig. 12. *Cerithium Saundersi*, sp. nov. Cuckhamsley. Montagu Smith Collection. Nat. size. 12a. Whorl,  $\times 1\frac{1}{2}$ . Drawn from a wax mould.
- 13, 14. *Lampusia* (?), sp. Cuckhamsley. Montagu Smith Collection. 13. Drawn from a wax mould,  $\times 1\frac{1}{2}$ . 14. Internal mould, nat. size.
15. *Avellana*, sp. (cf. *Humboldtii*, Müller). Cuckhamsley. Montagu Smith Collection. Drawn from a wax mould.  $\times 1\frac{1}{2}$ .
- 16, 17. *Dentalium turoniense*, sp. nov. Cuckhamsley. Montagu Smith Collection. 16. Internal mould, nat. size. 17. Ornamentation,  $\times 4$ .

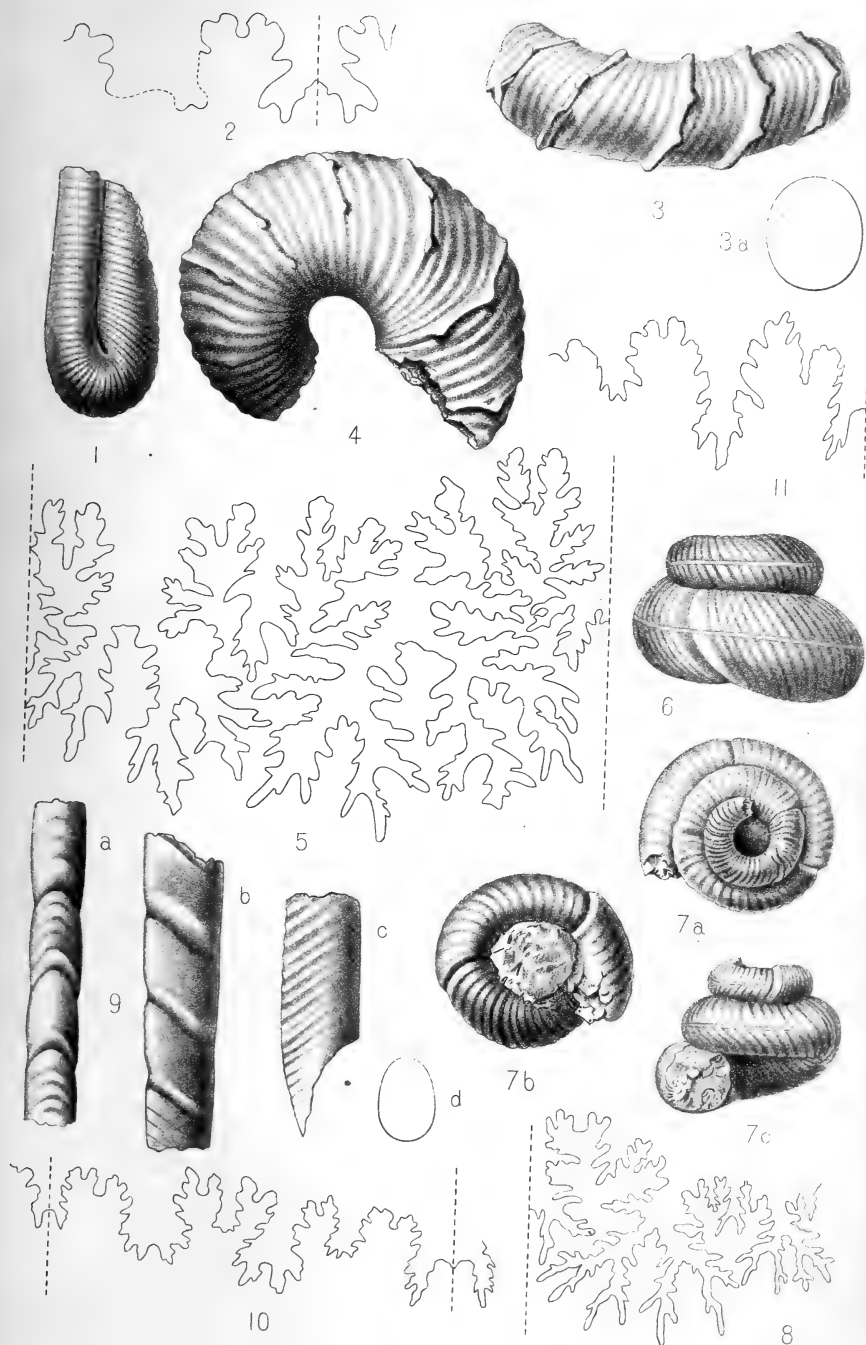
## DISCUSSION.

Dr. W. F. HUME pointed out, in connexion with the zonal name applied by Mr. Woods, that the horizon in question has already received the name of the *Holaster planus*-zone, that fossil being fairly abundant in England. The Author holds that the fauna is shallow-water in character, but *Trochus*, *Natica*, and *Dentalium* occur not uncommonly at over 1000 fathoms, while, with the exception of *Cerithium* and *Emarginulina* (the range of *Crepidula* and *Cinulia* had not been studied by the speaker), the others have all been found to range over 500 fathoms. Finally, the interesting comparison with the Lower Chalk fauna is one of the highest importance, and will prove helpful in determining the physical conditions of this disturbed period.

Mr. R. S. HERRIES was very glad that the Author was working out so interesting a fauna as that of the Chalk Rock. He wished, however, to protest against the invention of a new name for a horizon for which a very good one was already in existence; the more so as, if the proposed new name was persisted in, from what the previous speaker had said, there would be three names to signify the same bed.

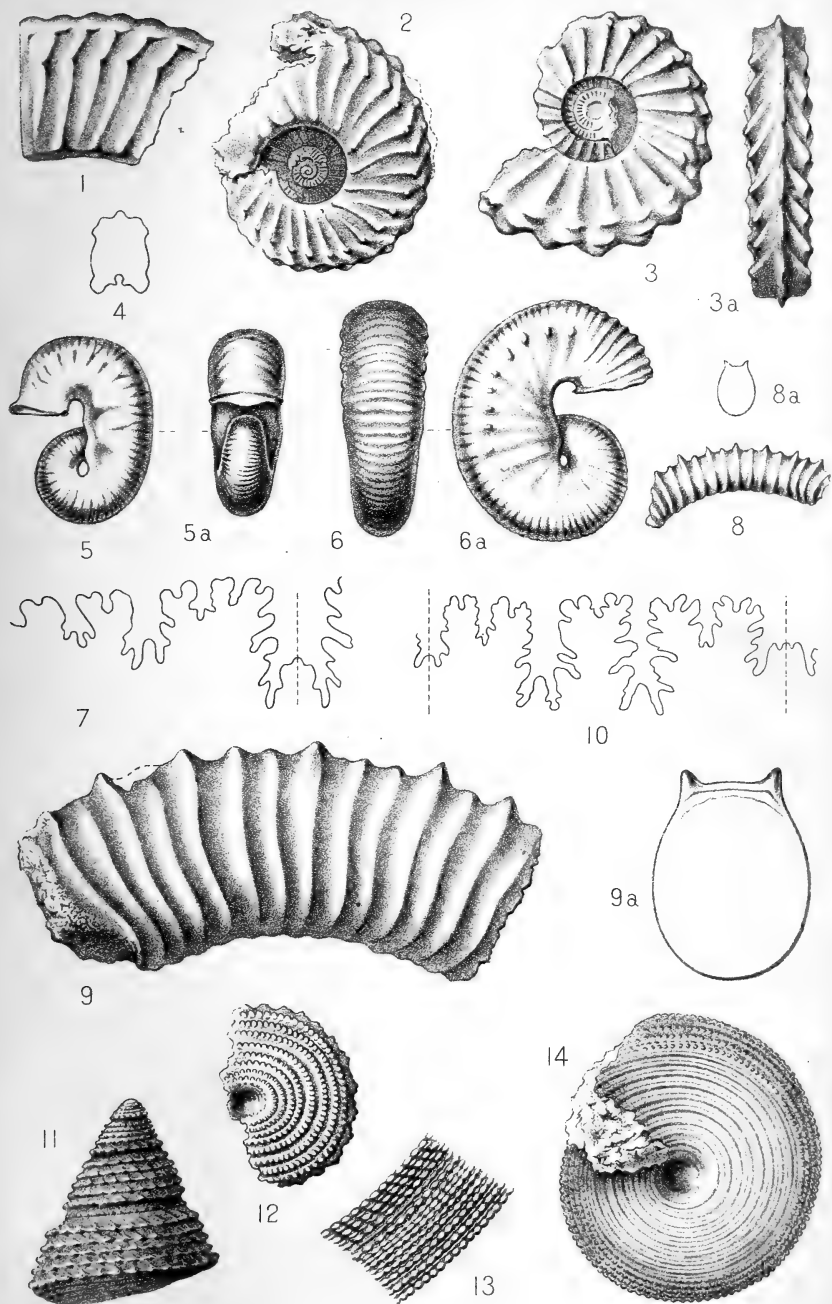
Prof. HULL, on the other hand, thought it desirable that a less 'insular' name should be substituted for that of 'Chalk Rock,' originally adopted by Mr. Whitaker. Now that it had been shown by the Author of the paper and others, such as M. C. Barrois, that this band was so rich in organic forms, and had so wide a range, not only in the British Isles but in Europe, he considered it desirable that some name of wider significance should be accepted, and one which would be recognized on the Continent; and as the name 'Zone of *Holaster planus*' had been suggested by M. Barrois, he hoped that it would be generally adopted by geologists.

Prof. H. G. SEELEY and Mr. J. E. MARR also spoke.



Edwin Wilson. Cambridge

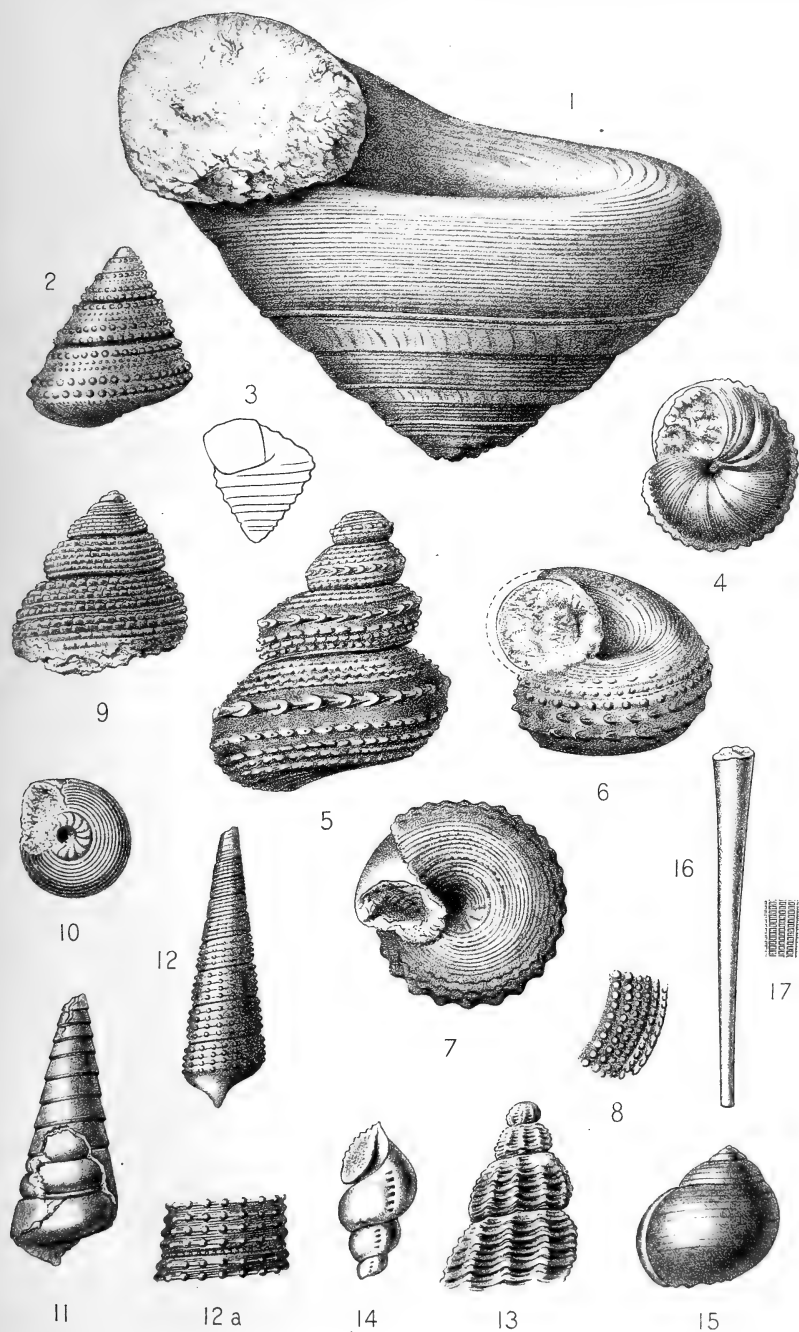




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**[No. 206 will be published on the 1st of next May.]**

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1896.

Wednesday, May .....	13-27
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7. *A DELIMITATION of the CENOMANIAN :—being a COMPARISON of the CORRESPONDING BEDS in SOUTH-WESTERN ENGLAND and WESTERN FRANCE.* By A. J. JUKES-BROWNE, Esq., B.A., F.G.S., and WILLIAM HILL, Esq., F.G.S. (Read January 8th, 1896.)

## [PLATE V.]

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## I. HISTORICAL INTRODUCTION.

THE object of this paper is to compare the beds which form the lower part of the Upper Cretaceous series in those parts of Western France and Western England which are nearest to one another. In England these beds are known by the names of Gault, Upper Greensand, and Lower Chalk; in France they are classed under d'Orbigny's 'Albien' and 'Cénomanién' stages. It is well known that in both countries the deposits referable to these groups change their lithological character so greatly, in passing towards the west and south-west, that different observers have formed different opinions in their attempts to correlate one area with another. Further, no geologist has yet endeavoured to make a careful comparison of the French and English types; but it is only by such a comparison that the true stratigraphical position of d'Orbigny's Cénomanién stage can be determined, and that the limits of this stage in areas outside the typical Cenomanian district can be fixed.

The name 'Cénomanién' was introduced by d'Orbigny in 1847 to designate the lower part of the series which he had previously called 'Turonien,' when he found that this lower portion contained a fauna essentially distinct from that of the upper part.<sup>1</sup> He then proposed to retain the name 'Turonien' for the upper part, and to adopt the name 'Cénomanién' for the lower part, taking the name from Le Mans, in the Sarthe, the *Cenomanum* of the Romans, and

<sup>1</sup> 'Paléont. Française: Terr. Crétacé,' vol. iv. p. 270. See also his 'Cours élémentaire de Paléontologie et de Géologie stratigraphiques,' 1852, vol. ii. p. 631.

regarding that district as the typical area of his new stage, because the deposits there were of considerable thickness and were rich in well-preserved fossils.

Unfortunately d'Orbigny himself fell into error regarding the deposits which should be included in his Cenomanian stage in the West of France. In the Sarthe there are no Lower Cretaceous strata, neither are there any beds containing a typical Albién fauna, so it is not surprising that d'Orbigny included the basal clays and greensands in his Cenomanian; but he also believed that his Albién stage was wanting near Havre, and that everything seen there above the Kimmeridge Clay was of Cenomanian age.<sup>1</sup>

This belief of d'Orbigny's was doubtless one cause which retarded the progress of opinion respecting the limits and components of the Cenomanian stage. Another cause is certainly to be found in the local and exceptional nature of the beds in the district which was chosen as the type, both as regards their lithological characters and the assemblage of fossils that they contain.

A study of what has been written by French geologists concerning the Cenomanian shows us that they have constantly found a difficulty in determining what beds in other parts of the country should rightly be regarded as the equivalents of the Cenomanian of the Sarthe.

In perusing the Vicomte d'Archiac's '*Études sur la Formation Crétacée*'<sup>2</sup> we have been struck by the general accuracy of his correlations. He evidently had a masterly grasp of the subject and a keen eye for the structure of a country, and for tracing definite horizons in a changeful group of beds. He anticipates d'Orbigny in separating the '*groupe de la craie tufau*' of Touraine and Anjou from his '*groupe du grès vert*,' and he divides each of these groups into three stages. It is possible that he made some mistakes in the determination of his fossils, but the grouping of his beds appears to be more correct, stratigraphically, than the grouping adopted by d'Orbigny in his '*Cours élémentaire de Pal. et de Géol. stratigraphiques*' of 1852. Certainly the comparisons made in his rapid traverse of the Sarthe, Orne, and Calvados are very correct, and we think that he laid a sufficiently accurate basis for a more detailed correlation of the Cenomanian deposits, if his successors had only worked along the same lines, and had not depended so entirely on the minutiae of palæontological evidence.

Unfortunately the late Prof. Hébert, influenced probably by the statements of d'Orbigny, and struck by the differences between the Cenomanian faunas of Havre and of Le Mans, propounded the hypothesis that the greater part of the Cenomanian of the Sarthe, or Grès du Maine, as he called it, was newer than the '*craie glauconieuse*' of Havre, and that the former was a local deposit which was not represented by anything on the northern coast. This was combated and disproved by M. Guillier and M. G. Bizet, who showed that chalky beds containing Rotomagian fossils occurred

<sup>1</sup> '*Cours élémentaire, etc.*' vol. ii, pp. 619 & 635.

<sup>2</sup> *Mém. Soc. Géol. France*, ser. 2, vol. ii. pp. 1-148 (1846), published 1847.



in the midst of the Grès du Maine, and that the 'Rotomagien' or Rouen Chalk is merely the chalky facies of the upper part of the Cenomanian of the Orne and Sarthe. This view has been accepted by Prof. A. de Lapparent and by the officers of the Service de la Carte géologique de France.

French geologists, however, have not reached the end of the difficulties and controversies to which the local and isolated facies of their typical Cenomanian has given rise. They are even now at variance with regard to the line of separation between the Albien and Cenomanian stages. The Albien fauna of d'Orbigny was mainly that of the Lower Gault; the fauna of what we know as the Upper Gault and Blackdown Beds was by d'Orbigny included partly in the Albien and partly in the Cenomanian, under the mistaken impression that our Blackdown Beds represented a part of his Cenomanian.

Gradually, however, it became known that between the typical Albien and Cenomanian faunas there was a distinct zonal assemblage in the Upper Gault of Wissant, in the Gaize of the Ardennes, and in the Vraconnien of the Jura. The question then arose as to whether this zone of *Ammonites inflatus* should be included in the Albien or in the Cenomanian, and on this question French geologists differ to the present day, some thinking with Prof. de Lapparent that it should be classed as part of the Albien, others agreeing with Prof. Hébert and Dr. Barrois in regarding it as Cenomanian.

Further, Dr. Barrois's researches in England and in the North-east of France disclosed the existence of beds containing *Pecten asper* between the zone of *Ammonites inflatus* and the base of the Chalk in those regions. Now *Pecten asper* is a common shell in the Cenomanian of the Sarthe, and consequently French geologists are all of opinion that the true Cenomanian contains an equivalent of this zone of *Pecten asper*.

In England, as Dr. Barrois has shown, the Upper Greensand of Wiltshire, Hampshire, and Dorset may be divided into two zones, the lower being his zone of *Ammonites inflatus*, the upper being his zone of *Pecten asper*, which includes the chert-beds and green sands of Warminster and other places. The result of French investigation, therefore, has been to tell us that our subdivisions into Gault, Upper Greensand, and Lower Chalk do not tally in any way with their Albien and Cenomanian stages, and that if we wished to adopt the French nomenclature we should have to draw a hard-and-fast line in the middle of our Upper Greensand.

Having thus briefly indicated the history of French opinion, and mentioned the difficulties which have arisen in comparing the sections on each side of the Channel with the beds in the area which was selected as the typical facies of the Cenomanian stage, let us now as briefly indicate the progress of English studies in the same field.

It is to William Smith that we owe the nomenclature and primary classification of the English Cretaceous strata: he found in Wiltshire and elsewhere a succession of (1) clay, (2) and,

and (3) chalk, to which he gave the simple names of (1) The Gault, (2) The Greensand, and (3) The Chalk. His Chalk was subsequently divided first into Lower and Upper, and more recently into Lower, Middle, and Upper. For a long time the Gault and Upper Greensand were regarded as distinct formations or stages, but the tendency of modern opinion has been to consider them as different lithological phases of one formation or stage, and we have no doubt that a new name will have to be found for this combined Gault-and-Greensand stage.

The work of English geologists has therefore tended to consolidate the Gault and Greensand, and to separate them as a whole from the overlying Lower Chalk, which has generally a bed of glauconitic marl at its base, and is often marked off from the Upper Greensand by a very clear plane of division. The fossil assemblages agree with this method of classification, and no modern English geologist would imagine that a more natural division could be made by grouping a part of the Upper Greensand with the Lower Chalk.

This being so, it has for some time seemed odd to us that a different line of division should be taken by French geologists, and the question occurred to one of us whether they were fully justified in correlating the beds which they group as Cenomanian. This idea was greatly strengthened by a recent examination of the Devon coast-sections where the Upper Greensand is well developed, but the Lower Chalk is represented by a peculiar set of arenaceous beds which differ from anything else in England. The fauna of these beds is also peculiar. It includes *Pecten asper*, and many species which in England are only found in the Upper Greensand,\* others which are proper to the Lower Chalk, and some which have only hitherto been found in France. Both of us were struck with the similarity of this fauna to that of the French Cenomanian.

Having thus obtained what promised to be a key to the difficulty—for if *Pecten asper* occurred in a representative of the Lower Chalk in England, it might do so also in France—we proceeded to enquire how far this occurrence of *P. asper* might be responsible for the supposed necessity of grouping the Greensand zone of *P. asper* in the Cenomanian stage. We found that the succession of beds in the department of the Sarthe had been carefully worked out,<sup>1</sup> that the similar series in the Orne had been examined and described by M. Bizet, of Bellême, and that the Havre and Rouen sections had been described by Prof. Hébert, M. Lennier, and others, but that little or nothing was known about the intervening area in the Calvados. So far as we could learn, no one had published any detailed comparison of the succession in the Orne and Sarthe with the sections near Havre, and consequently it was uncertain how far south the Gault extended, and whether the base of the Cenomanian in the Orne and Sarthe corresponded with any definite horizon at Cape La Hève. This want of continuous stratigraphical information certainly seemed to leave much to be desired in the way of evidence,

<sup>1</sup> See Guillier's 'Géologie de la Sarthe.'

and suggested that more accurate views might be obtained by an investigation of some of the principal exposures along a traverse from the coast in the direction of Lisieux, Vimoutiers, and Mortagne.

In planning out the route of this traverse we owe thanks to M. G. F. Dollfus, of Paris, and M. Bizet, of Bellême, for advice and information regarding the best localities to visit. The cliffs between Cape La Hève and Etretat were first studied in detail, and subsequently two excursions were made to localities in the Calvados and Orne, between Honfleur and Mortagne.

[*Note.*—It should be mentioned that the examination of the French sections was accomplished entirely by Mr. Hill, and that the exposures in the Calvados had to be discovered without guidance, except so far as the outcrops were shown on the sheets of the *Carte géologique détaillée de la France*. The Devon coast-sections were worked out by myself in 1894 for the Geological Survey, and the Director-General kindly permits us to publish some of the information then obtained.—A. J. J.-B.]

In arranging our descriptive notes for comparison we have thought it best to place the English sections first, because this part of the Cretaceous series is much more complete, more frequently exposed in coast-sections, and more clearly divisible into two distinct portions or stages than it is in France. Consequently we feel justified in taking the English succession as a standard, and in endeavouring to bring the French succession into accord with ours. We believe that we have succeeded in doing this, and that as a result we shall have supplied French geologists with a better and more definite base-line for their Cenomanian stage. We think that the present state of confusion has arisen from their having adopted an opposite course, for they have taken a local and incomplete set of beds as a standard, and have tried to fit the more normal and complete succession with this unsuitable type. It is just as if we had taken the Devon type of these two stages as a standard, and had endeavoured to correlate the Gault and Lower Chalk of Folkestone with that local and peculiar type—without studying the intervening exposures.

## II. A BRIEF DESCRIPTION OF SOME SECTIONS ON THE SOUTH COAST OF ENGLAND.

The sections which most clearly exhibit the relationship of the Gault, Upper Greensand, and Lower Chalk are those on the coasts of the Isle of Wight, Dorset, and Devon.

### 1. Isle of Wight.

The stratigraphic succession of these groups in the Isle of Wight is fairly well known on both sides of the Channel, to the French from the writings of Dr. Barrois, and to us from those and from the second edition of the Geological Survey memoir on the island; so that we need only call attention to such points as have a special bearing on our present purpose.

In the first place, it is worthy of note that all the component members of the Cretaceous system are thicker here than at any other place along the south coast. Taking the Gault and Upper Greensand together, they have a thickness of 270 feet at Gore Cliff and of about 230 at Compton Bay, while the Lower Chalk is 200 feet thick near Culver Point, and is probably but little less at Compton Bay.

In the next place, no hard-and-fast line can possibly be drawn between the Gault and Upper Greensand; there are a set of passage-beds, sandy micaceous clays, which have been referred to the Gault by some authors and to the Greensand by others. As *Ammonites rostratus* was obtained from these sandy clays by the Survey fossil-collector, it would appear that they belong to the same zone as the overlying micaceous sands, and should not be referred to the Lower Gault.

Whether these passage-beds be included in Gault or in Greensand, it is equally impossible to take a definite base-line for the zone of *Ammonites rostratus*. There is the same kind of passage in other parts of England, and so long as the *Amm. rostratus*-beds are regarded merely as a zonal subdivision of the Gault-and-Greensand group there is nothing surprising in it. Dr. Barrois has taken the base of the yellow sands near Ventnor as the base of the Cenomanian stage in England,<sup>1</sup> but the bed of sandstone which there forms a convenient base-line has not been detected in other parts of the island. His endeavour to fix the base of the zone of *Amm. rostratus* and to make it the base of an English Cenomanian is no doubt a logical application of the classification which he had adopted for the beds in the East of France, but we think that arrangement was founded on a mistaken view of the chronological value of the typical Cenomanian of Maine and Normandy, a view which may be traced to the erroneous correlations of Prof. Hébert.

The next point for consideration is the junction of the zone of *Ammonites rostratus* with that of *Pecten asper*. This is of importance because some French geologists, notably Prof. de Lapparent, are prepared to throw the former into the Albien and to take the latter as commencing the Cenomanian. In the Isle of Wight, however, there is no break or great change of fauna at this horizon: the chert-beds are mere local deposits of organic silica (sponge-spicules), and *Pecten asper* occurs below as well as above them. No English geologist would think it natural to detach these beds from the Greensand and to group them with the Lower Chalk.

When we come to the junction of Chalk and Greensand, however, the case is different. Even here there is a passage and no sharp line of demarcation, but the passage is very rapid and it coincides with a great change in the fauna. Above the highest layer of cherts there are two beds which we should group with the Upper Greensand, and the uppermost of these passes into what we regard as the true Chloritic Marl or basement-bed of the Chalk. The

<sup>1</sup> 'Recherches sur le Terrain Crét. Sup. de l'Angleterre et de l'Irlande,' Lille, 1876.

following section was taken by one of us in 1880 from the slipped mass at Collins Point, near Ventnor :—

		Feet.
CHALK.	6. Chalk Marl with scattered glauconitic grains near the base, <i>Ammonites varians</i> and <i>Pecten Beaveri</i> .....	5
	5. Greenish-buff glauconitic marl full of fossils and phosphatic nodules, <i>Ammonites varians</i> , etc. ....	3½
	4. Compact, dark green, sandy marl, with quartz and glauconite, but few fossils or phosphatic nodules .....	2½
	3. A layer enclosing lumps of calcareous sandstone partially phosphatized, irregular pieces of dark phosphate and broken <i>Pecten asper</i> .....	about 0½
UPPER GREENSAND.	2. Yellowish-green sand mottled with darker green; yields <i>Pecten orbicularis</i> , <i>Ostrea vesiculosa</i> , and <i>Pecten asper</i> .	2
	1. Continuous layer of dark-grey cherty stone with compact green sand below, seen for .....	5

The material of 2 passes into that of 4 between the lumps of phosphatized stone in 3. At Niton 3 and 4 form a kind of boulder-bed full of such lumps, with phosphatized sponges, *Cardiaster fossarius*, *Pecten asper*, *Terebratella pectita*, and other fossils, but without any *Ammonites*. The Chloritic Marl (5), on the other hand, might be called a 'Cephalopoda Bed,' so abundant are ammonites of the species *variens*, *Coupei*, and *Mantelli*, with *Turritiles tuberculatus* and *Morrisii*. It is also characterized by the remarkable siliceous sponge *Stauroonema Carteri* (Sollas), which has not yet been found below this horizon, nor far above it.

As one of us spent a week in 1880 for the purpose of examining these beds at the base of the Chalk, and afterwards engaged the services of Mr. M. Norman, of Ventnor, in collecting carefully from them, it seems desirable to give the list of fossils then obtained, in order to show the difference of the faunas. In this list the numbers above the columns indicate the beds as numbered in the section just described :—

	2.	3, 4.	5.
PORIFERA (SPONGES).			
<i>Halirrhoea agariciformis</i> (phosphatized).....	...	*	...
<i>Plocoscyphia labrosa</i> , Smith (phosphatized) ...	...	...	*
<i>Jerea Websteri</i> .....	...	*	...
<i>Siphonia</i> (phosphatized) .....	...	*	...
<i>Stauroonema Carteri</i> , Sollas .....	...	...	*
ACTINOZOA.			
<i>Micrabacia coronula</i> , Goldf. ....	...	...	*
ECHINODERMATA and ANNELIDA.			
<i>Cardiaster fossarius</i> , Benett .....	*	*	...
<i>Discoidea subucula</i> , Leske .....	...	...	*
<i>Hemiaster Morrisii</i> , Forbes .....	...	...	*
<i>Holaster levis</i> , var. <i>carinatus</i> .....	*	*	*
<i>Serpula</i> , sp. ....	...	...	*
<i>Vermicularia umbonata</i> , Sow. ....	...	...	*

TABLE continued.

	2.	3, 4.	5.
<b>BRACHIOPODA.</b>			
<i>Megerlia (Kingena) lima</i> , DeFr. ....	...	...	*
<i>Terebratella pectita</i> , Sow. ....	...	*	*
<i>Terebratulina striata</i> , Wahl. ....	...	...	*
<i>Terebratula bispicata</i> , Sow. ....	...	*	*
<i>semiglobosa</i> (?), Sow. ....	...	...	*
<i>Rhynchonella Grasiana</i> , d'Orb. ....	...	...	*
<i>Mantelliana</i> , Sow. ....	...	...	*
<b>LAMELLIBRANCHIATA.</b>			
<i>Anomia</i> , sp. ....	...	...	*
<i>Ostrea vesicularis</i> , Lam. ....	*	...	*
<i>vesiculosa</i> , Sow. ....	*	*	*
<i>carinata</i> , var. <i>frons</i> , Park. ....	...	...	*
<i>Plicatula pectenoides</i> , Sow. ....	*	*	*
<i>inflata</i> , Sow. ....	*	...	*
<i>Pecten asper</i> , Lam. ....	*	*	...
<i>Galliennii</i> , d'Orb. ....	*	...	...
<i>orbicularis</i> , Sow. ....	*	*	*
sp. nov. (allied to <i>fissicosta</i> , Eth.) ....	...	*	...
<i>Janira quadricostata</i> , Sow. ....	*	...	...
<i>quincocostata</i> , Sow. ....	...	*	*
<i>Lima globosa</i> , Sow. ....	*	...	*
<i>Cardium hillanum</i> (?), Sow. ....	...	...	*
<i>Arca Mailleana</i> , d'Orb. ....	...	...	*
<i>obesa</i> (?), Pict. & Roux ....	...	...	*
<i>Crassatella</i> , sp. (casts) ....	...	...	*
<i>Cardita tenuicosta</i> (?), Sow. ....	...	?	*
<i>Cyprina quadrata</i> , d'Orb. ....	...	...	*
<b>GASTEROPODA.</b>			
<i>Avellana cassis</i> (?), d'Orb. ....	...	*	...
sp. ....	...	...	*
<i>Pleurotomaria Rhodani</i> , d'Orb. ....	...	*	*
<i>Solarium ornatum</i> (?), Sow. ....	...	*	*
<b>CEPHALOPODA.</b>			
<i>Ammonites Mantelli</i> , Sow. ....	...	...	*
<i>navicularis</i> , Mant. ....	...	...	*
<i>varians</i> , Sow. ....	...	...	*
var. <i>Coupei</i> , Brong. ....	...	...	*
<i>Turritites Morrisii</i> , Sharpe ....	...	...	*
<i>tuberculatus</i> , Bosc ....	...	...	*
<i>Hamites armatus</i> (?), Sow. ....	...	...	*
<i>Nautilus subradiatus</i> , d'Orb. ....	...	...	*
<i>expansus</i> , Sow. ....	...	...	*

This list appears to show that it is Bed 5 only which contains the characteristic fossils of the Chloritic Marl, and that in passing from 4 to 5 we cross the plane of division which separates two important faunas and two primary subdivisions or stages of the Upper Cretaceous Series. There are of course some species, particularly of

lamellibranchiata, which pass from one stage to the other, but the sudden incoming of a new and varied set of cephalopoda is sufficient to mark off one fauna from the other.

With respect to the Chalk Marl little need be said; it consists of alternating soft and hard beds, and the most abundant cephalopods are *Ammonites Mantelli*, *Amm. navicularis*, *Amm. varians*, *Turritiles costatus*, *T. Scheuchzerianus*, *T. tuberculatus*, *Baculites baculoides*, and *Scaphites æqualis*.

The higher part of the Lower Chalk is massive, white, and comparatively unfossiliferous, but at the top is a band of grey marl (zone of *Belemnitella plena*).

## 2. Dorset.

In Dorset both the stages above described—*i. e.* (1) the combined Gault and Greensand, (2) the Lower Chalk—are much thinner than in the Isle of Wight. The Gault-and-Greensand stage averages from 140 to 160 feet thick, but, instead of becoming steadily thinner to the west, the minimum thickness seems to be at Whitenose, near Weymouth, and in the extreme west of the county it swells out by the addition of sandy matter to about 200 feet. The Lower Chalk is about 140 feet thick near Swanage, but thins to less than 40 at Lulworth and Whitenose; whether it continues to thin towards the west is not known, as it is faulted out for a considerable distance and does not appear in the cliffs of West Dorset.

The most easterly cliff-section is at Ballard Hole or Punfield Cove near Swanage. This was well described in 1876<sup>1</sup> by Mr. H. G. Fordham, and, checking his account by Mr. Strahan's more recent measurements,<sup>2</sup> we have the following sequence:—

### Section at Ballard Hole.

	Feet.
	{ Buff-coloured marl (zone of <i>Belemnitella plena</i> ) ..... 6
	{ Alternations of hard whitish chalk and layers of grey marl. 84
	{ Yellowish sandy chalk with phosphate-nodules ..... (?) 6
	{ Whiter chalk with a hard bed at the base full of <i>Brachiolites</i> ( <i>Plocoscyphia</i> ) and some phosphates ..... 13
LOWER CHALK	{ Marly chalk, in alternating white and grey beds passing down into the next ..... 30
143 feet.	{ Glauconitic marl with fossils and phosphate-nodules, <i>Ammonites varians</i> , <i>Scaphites æqualis</i> , <i>Holaster subglobosus</i> , etc. (Chloritic Marl) ..... 4
	{ Nodular sandstone, consisting of irregular lumps of calcareous sandstone embedded in greenish sand, <i>Pecten asper</i> , <i>P. orbicularis</i> , <i>Ostrea vesiculosa</i> ..... 5
	{ Greenish sand with occasional calcareous concretions ..... 4
'UPPER GREENSAND,'	{ Green sand without calcareous nodules, but with scattered fragments of brown phosphate, <i>Amm. rostratus</i> ..... 17
71 feet	{ Two layers of greenish sandstone with dark green sand between them ..... 5
	{ Bluish sandy clay with three stone-beds, one at the base; <i>Ammonites rostratus</i> , <i>Cucullæa glabra</i> , <i>Thetis Sowerbyi</i> , <i>Arca carinata</i> , and <i>Vermicularia concava</i> ..... 40
GAULT.	{ Blue sandy clay passing down into stiffer clay ..... (?) 84

<sup>1</sup> Proc. Geol. Assoc. vol. iv. p. 506.

<sup>2</sup> Geol. Surv. Mem. 'Geology of the Isle of Wight,' 2nd ed. 1889, p. 66.

How much of the Lower Chalk should be regarded as belonging to the zone of *Ammonites varians* is doubtful, but it probably includes the sandy chalk with phosphates, and this would make a thickness of 53 feet.

It is especially noteworthy that there can be no doubt where the line between Chalk and Greensand should be drawn in this section. Here everyone has taken the same horizon, for there is no passage as in the Isle of Wight, but an abrupt change or break at the base of the Chloritic Marl, which rests on an irregular surface of the underlying sandstone as if a certain amount of current-erosion had taken place before its deposition.

The nodular sandstone is clearly the equivalent of the beds which contain similar concretions and the same fossils in the Isle of Wight, but the chert-beds are absent; as, however, they are only 13 feet thick at Compton Bay according to Mr. Strahan, it is not surprising to find them absent here. They are in fact a local and variable set of beds, and are absent over a large part of Dorset, though where present they always come in at the same horizon, and, as we shall presently see, they set in again a little farther west.

At Ballard Hole *Pecten asper* has only been found in the nodular sandstone, but as the sandy material of this bed passes down into the greensand below it is impossible to say how much should be included in this zone. There is in fact a complete passage down into sand that contains *Ammonites rostratus*.

As in the Isle of Wight, different observers have drawn the line between Greensand and Gault at different horizons. Mr. Fordham takes the Upper Greensand down to the lowest stone-bed and thus gives a thickness of 71 feet to this division. Mr. Strahan draws the line higher up, assigning only 45 feet to the Greensand and 110 to the Gault. Neither have attempted a division into zones, and we do not yet know how much of this thickness should be assigned to the zone of *Ammonites rostratus*, and how much to those of *A. lautus* and *A. interruptus*; it is not probable, however, that the division into zones would coincide with either of the lines taken to separate Gault from Greensand.

The next fairly complete and accessible section is at Lulworth. The Lower Chalk was measured here by one of us in 1892, and found to be only 38 feet thick, a remarkable diminution of thickness. Dr. Barrois gave a detailed account of the Greensand portion in 1876,<sup>1</sup> and Mr. Mejer has kindly supplied us with a note on the beds at the junction of the Chalk and Greensand. Combining these sources of information, we have the following sequence:—

<sup>1</sup> 'Recherches sur le Terr. Crét. Supérieur, etc.,' p. 89.



*Section at Lulworth Cove.*

	Feet,
LOWER CHALK.	{ Soft, greenish, buff-coloured marl (zone of <i>Bel. plena</i> )..... 6
	{ White chalk in regular beds, divided by thin seams of marl 16
	{ Soft, whitish chalk, blocky and not bedded, enclosing siliceous nodules or flints..... 12
	{ Glauconitic chalk with phosphatic nodules ..... 4
ZONE OF Pecten asper.	{ Hard, nodular, calcareous sandstone (1 foot), passing down into similar but more sandy and evenly-bedded rock; many fossils ..... 8
	{ Sand with two or more layers of chert ..... 5
	{ Marly greensand with small phosphatic nodules, <i>Pecten asper</i> and many other fossils ..... 7
ZONE OF AM. ROSTRATUS.	{ Greensand with beds of calcareous sandstone ..... 14
	{ Greenish sand with an oyster-bed 10 feet down and a layer of fossiliferous concretions at the base ..... 16
	{ Grey micaceous sands with two layers of grey sandstone: <i>Vermicularia concava</i> ..... 44
GAULT.	{ Black sandy clay, seen for ..... 15
	{ Dark blue clays..... (?) 45

In this section a noteworthy point is the occurrence of flints in the Lower Chalk. These flints do not disengage themselves like ordinary chalk-flints, but have more resemblance to the siliceous concretions which occur in the Lower Chalk of Wiltshire.<sup>1</sup> They are enveloped in a thick coat of white siliceous chalk, which often seems to pass inward into grey or black flint and outward into the pure chalk. The amount of completely silicified matter or flint varies greatly, being sometimes a fairly large mass and sometimes a mere nucleus, and some concretions have none at all.

These flints also occur at Whitenose and in many other parts of West Dorset, and we call especial attention to them, both because the idea that real flints do not occur in Lower Chalk is still current in some quarters, and because siliceous concretions of the nature of cherts occur in the Cenomanian of Normandy.

Lithologically there is nothing at Lulworth which can be called Chalk Marl, but, as Dr. Barrois records *Ammonites varians* and *Rhynchonella Mantelliana* from these beds at Ringstead Bay, they may represent part of the Chalk Marl. Whether the basement-bed with its phosphate-nodules represents the true Chloritic Marl or *Stauronema*-bed we think very doubtful; more probably it should be regarded as a condensed equivalent of the lower part of the Chalk Marl.

The junction of Chalk and Greensand is even more abrupt and well marked than at Punfield, the base of the glauconitic chalk resting on an uneven and current-washed surface of the underlying sandstone. The uppermost foot of this sandstone, moreover, is rough, nodular, and more calcified than the part below, as if it had been exposed to some alterative influences before the deposition of the overlying chalk.

The zone of *Pecten asper* is well marked; the chert-beds are coming in again, and, with a marly greensand below, in which Dr. Barrois also found *P. asper*, give the zone a thickness of 20 feet.

<sup>1</sup> See Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 403.

But, with the exception of a rare specimen of *Ammonites Mantelli*, the Chalk Marl cephalopoda do not descend below the base of the Chalk.

The section at Whitenose appears to be similar to that at Lulworth, but thence westward there is no cliff-section of Cretaceous rocks for a long distance. Inland exposures as far west as Bridport show a sequence like that of Lulworth; the Lower Chalk is as thick or thicker, and has the same fossiliferous nodule-bed at the base.

Between this district and Pinhay, near Lyme Regis, a distance of about 14 miles, the whole of the Chalk has been removed by Tertiary erosion, but sections of the Gault and Greensand show that this lower stage attained a thickness of nearly 200 feet in the extreme east of Dorset.

### 3. Devon.

We now come to Devon, where the Greensand attains a great thickness, and the representative of the Lower Chalk differs as much from the ordinary English type as that does from the French Cenomanian. We have seen that in West Dorset the Lower Chalk is still chalk with a definite basal nodule-bed. Where the Chalk comes in again below Pinhay, west of Lyme, the succession at the junction of Chalk and Upper Greensand is as follows:—

#### Section below Pinhay.

		Feet.	In.
T.	7. Hard, rough, nodular chalk, with <i>Inoceramus mytiloides</i> , <i>Cardiaster pygmaeus</i> , and <i>Cidaris hirudo</i> .....	1	9
	6. Hard glauconitic chalk, with <i>Inoceramus mytiloides</i> and <i>Cidaris hirudo</i> .....	1	9
	5. Softer chalk, full of quartz and glauconite, with many phosphate-nodules and derived fossils at the base.....	0	9
M.	4. Hard, rough, quartziferous limestone with large green-coated lumps, fossils not abundant. About.....	1	0
	3. Hard, compact, shelly limestone, fine-grained above, but coarse and quartzose at the base, which rests on an eroded surface of the bed below .....	1	6
G.	2. Calcareous sandstone with few fossils, indurated and calcified in the upper part, softer below .....	8	0
	1. Chert-beds, fine sandstone with irregular concretions of chert, seen for.....	22	0

These beds fall into three natural groups as bracketed, which we may for the present call G, M, T.

*Group G* is clearly the higher part of the Upper Greensand, and the calcareous sandstone occupies the place of the similar bed in Dorset. *Pecten asper* has not been found in it, but the fossils which do occur are those of its Dorset equivalent.

*Group M.*—All the beds above the calcareous sandstone are very variable in thickness. Nos. 3 and 4 are in one place less than a foot thick, but expand in a short distance to more than 3 feet. The lower bed contains a mixture of fossils which are elsewhere characteristic of separate zones; some of the so-called ‘zone of

*Pecten asper*,<sup>1</sup> such as *P. asper* itself, *P. Galliennae*, and *Catopygus carinatus*; some of the Lower Chalk, such as *Ammonites varians*, *A. Mantelli*, and *Scaphites æqualis*; near the base, too, a peculiar large coralloid polyzoan (*Ceriopora ramulosa*) is not uncommon. The upper bed has fewer fossils, but the same ammonites occur with, occasionally, *Scaphites æqualis*. These two beds are well marked off from those above and below, and may be called the zone of *Ammonites Mantelli*.

The upper surface of No. 4 is always a layer of brown phosphatic nodules; these are now 'welded' on to this bed, but the interstices between them are filled with the material of the overlying bed. This bed, No. 5, is full of large grains of quartz and glauconite, but has a chalky matrix, and is much more friable than the bed below. Setting aside the derived phosphatic fossils, of which there are many, the commonest fossil in bed 5 is *Rhynchonella Wiestii*, a species which is closely allied to *Rh. Cuvieri*. With it are found *Belemnitella plena* and *Discoidea cylindrica*, so that, looking to the fossils, the bed would seem to be the equivalent of the *Belemnitella*-marls of Dorset and other counties. Physically, however, it is the base of the Middle Chalk or Turonian, for it passes up into the hard glauconitic chalk which contains only Turonian species.

As to the succeeding yellowish nodular chalk, there can be no doubt regarding its age; it has some resemblance to the Melbourn Rock, and may be regarded as its equivalent. We think, therefore, that the Middle Chalk has here a basement-bed of gritty glauconitic chalk, containing derived fossils, which bears the same relation to the Melbourn Rock as the basement-bed in Dorset does to the Chalk Marl.

If the above inferences are correct, the only beds which can be regarded as the equivalents of the Lower Chalk in this section are Nos. 3 and 4. Mr. C. J. A. Meyer saw these beds in 1895, and at once recognized No. 3 as a union of the 10 and 11 of his Beer Head section,<sup>1</sup> No. 4 as his bed 12, and the overlying beds as his 13 and 14. He is now, however, prepared to agree with our correlation of these beds.

Group M, the zone of *Ammonites Mantelli*, can be followed above the landslips of the coast-line between Lyme Regis and Axmouth running out near the top of Haven Hill, above the mouth of the Axe.

West of Seaton the Greensand and Chalk are brought in again by a fault and a syncline, an excellent section being exposed along the face of Whitecliff. The details of this will be given in the Survey Memoir, and it is only necessary to notice here that the glauconitic chalk (No. 5) is absent, the hard nodular yellowish chalk (No. 6) resting directly on the zone of *A. Mantelli*. The latter, moreover, forms one massive bed from 2 to 3 feet thick, though careful examination shows that beds 3 and 4 enter into its composition.

The Upper Greensand is about 160 feet thick, including a sandy

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxx. (1874) p. 369.

HOOKEN CLIFF,  
W. OF  
BEER HEAD.

(Scale: 1 inch = 10 feet.)

PINHAY,  
NEAR LYME REGIS.

Meyer's  
Beds.

BEER HEAD.

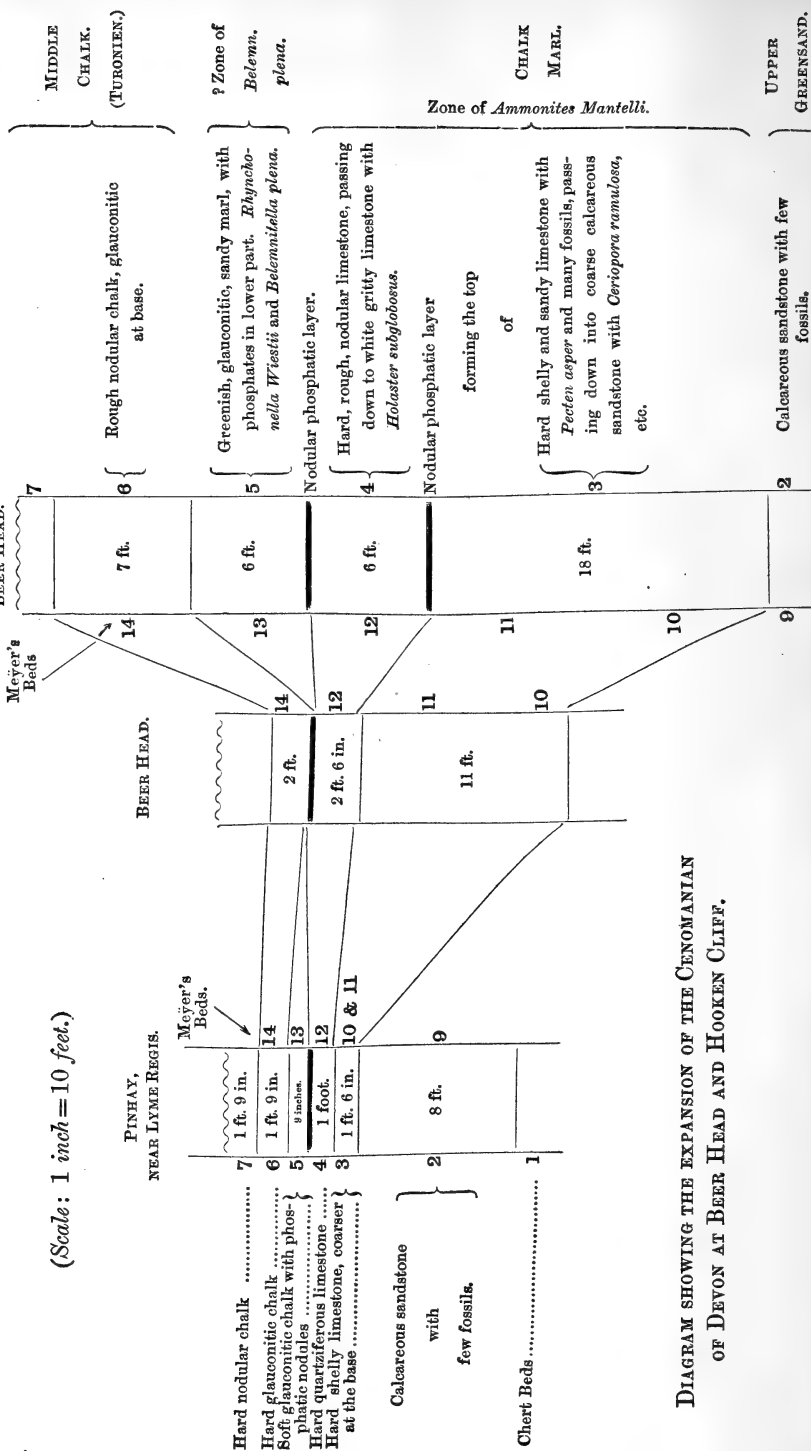


DIAGRAM SHOWING THE EXPANSION OF THE CENOMANIAN  
OF DEVON AT BEER HEAD AND HOOKEN CLIFF.

representative of the Gault. The following is a condensed view of the beds which compose this stage in Whitecliff:—

	Feet.
Hard calcareous sandstone, few fossils .....	8
Yellowish sand and sandstone, with numerous layers of chert ...	56
Dark green sand and hard glauconitic stone.....	4
Green, grey, and purple sand, with layers and concretions of hard calcareous sandstone.....	70
Dark green argillaceous sand seen for .....	15
	<hr/> 153

The beds at the junction of the Chalk and Greensand may be followed along the foot of the magnificent range of cliffs which extends from Beer Harbour to Beer Head, and near that headland the zone of *Ammonites Mantelli* can be seen to thicken out rapidly, the thickening being chiefly produced by the addition of material to its lower bed, till at Beer Head the whole is about 14 feet thick, and is very clearly divisible into two parts or beds. The upper bed,  $2\frac{1}{2}$  feet thick, is a rough quartziferous limestone with layers of green-coated nodules, and in it *Holaster subglobosus* is common; the lower bed is in its higher part a hard shelly and gritty limestone, with *Pecten subinterstriatus*, *P. asper*, *Ammonites Mantelli*, *Rhynchonella dimidiata*, *Pseudodiadema variolare*, and many other fossils; in this higher part the grains of quartz and glauconite are small, but in the lower 5 feet the former are large and the rock becomes a rough and coarse calcareous grit, in which the most abundant fossil is the large, branching, coral-like *Ceriopora ramulosa*. The plane of division between its base and the Upper Greensand below is well marked.

These two beds include Mr. Meyer's beds 10, 11, 12, but there is no clear representative of his 13, the glauconitic chalk or marly greensand, though there are patches and nests of such sand at the base of the overlying chalky limestone (Turonian).

We now come to the place where these beds attain their greatest development; this is in the great Southern-down landslip, and in the cliff from which it was detached, known as Hooken Cliff. Here the zone of *Ammonites Mantelli* is 24 feet thick, and the succession is as follows:—

		Feet.
TURONIAN.	6. Hard, rough, nodular chalk, glauconitic at base ...	7
	5. Greenish, sandy, glauconitic marl, with a few brown phosphate-nodules in the lower part; <i>Rhynchonella Wiestii</i> , <i>Belemnitella plena</i> , etc.....	6
	4. Layer of brownish green-coated nodules at top of hard, rough, nodular limestone, passing down into white gritty limestone with <i>Holaster subglobosus</i> .	6
ZONE OF AMM. MANTELLI.	3. Hard, rough, nodular layer with phosphatic matter, passing down into hard shelly and sandy limestone with <i>Pecten asper</i> and many other fossils; the quartz-grains getting larger in the lower part, and the rock passing into a coarse calcareous sandstone with 'corals' .....	18
UPPER GREEN- SAND.	2. Even-grained calcareous sandstone with few or no fossils .....	?

The numbers above given correspond with those of the Pinhay section, and the whole is, in fact, an expanded counterpart of that section (see p. 112). The upper surfaces both of 3 and 4 are more clearly marked, while the glauconitic chalk (No. 5), as near Lyme Regis, passes up into the hard rough nodular chalk above, which contains *Echinoconus subrotundus*. It is a remarkable instance of the rapid changes which take place in these beds that this No. 5 should be here 6 feet thick, though at Beer Head, only 400 yards away, it is represented merely by small nests of sand.

We are able to state that, as a result of revisiting this section in company with one of us, Mr. Meyer no longer maintains his correlation of his beds 10, 11, 12 (our zone of *Amm. Mantelli*) with the Warminster Greensand or with the Chloritic Marl, nor of his 13 and 14 with the Chalk Marl. He had in 1874 perceived the clear lines of demarcation which exist at the top of his No. 9 and at the top of No. 12, and he now agrees with us that the beds so limited must represent either the whole or a part of the Lower Chalk.

It is quite possible that only a part of the Lower Chalk is here represented; for, whether we take bed 5 of our section to be the zone of *Belemnitella plena* or the base of the Middle Chalk, there is clearly a break between it and the bed below, so that we may assume that there is nothing to represent that part of the Lower Chalk which lies between the zone of *Ammonites varians* and that of *Belemnitella plena*.

Whether material was deposited here and afterwards washed away by current-erosion, or whether no deposition took place in the interval, it is at present impossible to say, but for our present purpose it is sufficient that there is here an arenaceous representative of the Chalk Marl containing most of the characteristic fossils of that marl mixed with a number of other species which are evidently shallow-water forms, and these species are, as we shall see, almost all found in the Cenomanian of the Sarthe.

Confirmation of our reference of these beds to the lower part of the Lower Chalk is found in the neighbourhood of Chard and Chardstock, the latter place being only 9 miles north of Lyme Regis. The succession here has been accurately given by Mr. H. B. Woodward,<sup>1</sup> and so far as the Upper Greensand is concerned it resembles that of the coast-section. The upper surface of the Greensand is a well-marked plane, and upon it rests a hard quartziferous and glauconitic chalk crowded with fossils; this passes up into softer glauconitic chalk, which rapidly graduates into chalk with few fossils. Of this white chalk there is probably 30 or 40 feet, and there is some thickness of yellowish marl above it, all belonging to the Lower Chalk.

The basement of this Lower Chalk has been called Chloritic Marl, and it has long been celebrated for the abundance and good preservation of its fossils. The assemblage, however, is rather that of the whole Chalk Marl than that of the Chloritic Marl of the Isle of Wight, and it also includes some of the rare and peculiar species

<sup>1</sup> 'Geology of England and Wales,' 2nd ed. 1887, p. 392.

ISLE OF W.		Feet.	BEER HEAD.	
LOWER CHALK.		14	Limestones.	Cenomanian.
	Blocky C	64	Chert Beds.	
		58	Grey and Buff Sands.	
	Chalk M	35	Argillaceous Sands.	
GAULT AND GREENSAND.	Chert B			'GREENSAND.'
	Grey & Yellow S			
	Sandy & G			





TABULAR VIEW OF SOUTH-COAST SECTIONS.

(Scale : 1 inch = 100 feet.)

	ISLE OF WIGHT. Feet.	SWANAGE. Feet.	LULWORTH. Feet.	BEER HEAD. Feet.	
LOWER CHALK.	Blocky Chalk. 6	Blocky Chalk. 6	Blocky Chalk. 6	14	Limestones. Cenomanian.
	Blocky Chalk. 83	Blocky Chalk. 84	Chalk with flints. 1	64	Chert Beds.
	Chalk Marl. 120	Chalk Marl. 48	Chert Beds. 20	58	Grey and Buff Sands.
GAULT AND GREENSAND.	Chert Beds. 4	Green and Grey Sands. 66	Grey Sands and Sandstones. 74	35	Argillaceous Sands.
	Chert Beds. 27	Sandy Clays and Gault. 84	Sandy Clay and Gault. 60		
	Grey and Yellow Sands. 85				
	Sandy Clays and Gault. 145				



which occur in the quartziferous limestones of the coast. It is especially rich in ammonites, and nearly all the species occurring at Chard are found also in our coast-zone of *Ammonites Mantelli*, as will be seen from the list given on p. 159.

The relative thickness of the beds in the principal sections above described is shown in the accompanying 'Tabular View.'

### III. A STUDY OF THE CLIFFS BETWEEN CAPE LA HÈVE AND BRUNVAL.

The bold and almost unbroken line of cliffs which form the French coast from Cape d'Antifer to Cape La Hève present a section of the Cretaceous series from the higher zones of the Upper Chalk seen at the first-named promontory to the yellow sands which form the basement-bed, and which can be seen overlying the Jurassic rocks at Cape La Hève.

The general trend of these cliffs is about N.N.E. and S.S.W., but at the mouth of the Seine, after passing the lighthouses at Cape La Hève, the cliff turns to the south, making an obtuse angle to the general coast-line.

Between Cape La Hève and St. Jouin, a distance of some 11 miles, the strata are nearly horizontal, and the series seen are the beds from the base of the Cretaceous series to an horizon equivalent to our Grey Chalk; but at St. Jouin the beds dip gradually to the eastward, and the whole series is brought down to sea-level.

The section has been well studied by many French geologists, notably by MM. Lesueur,<sup>1</sup> le Vicomte d'Archiac,<sup>2</sup> Hébert,<sup>3</sup> de Lapparent,<sup>4</sup> and Lennier,<sup>5</sup> but even their descriptions do not furnish a complete account of the whole section, nor do they give full lists of the fossils found in the various beds.

Moreover, since De la Beche's visit in 1821,<sup>6</sup> and Mr. Pratt's<sup>7</sup> notice in 1837, no English geologist seems to have studied this fine section. Those who have described English Cretaceous fossils seem to have taken it for granted that the Cenomanian of Normandy included representatives of both our Upper Greensand and Lower Chalk; but, so far as we can ascertain, no one has hitherto attempted to ascertain how much of this Cenomanian would be regarded as the equivalent of the Lower Chalk. This has been our endeavour, but before entering into details we give the general succession of the series below the Turonian, as seen in the cliffs. This is as follows in descending order, the grouping being that of M. Lennier and Prof. de Lapparent:—

<sup>1</sup> 'Vues et Coupes des Environs du Havre,' Paris, 1843.

<sup>2</sup> 'Études sur la Formation Crétacée,' Mém. Soc. Géol. France, ser. 2, vol. ii. p. 95.

<sup>3</sup> Bull. Soc. Géol. France, ser. 2, vol. xxix. (1872), p. 446; *ibid.* ser. 3, vol. iii. (1875) p. 512.

<sup>4</sup> 'Traité de Géologie,' 2nd ed. 1885, p. 1074.

<sup>5</sup> Bull. Soc. Géol. Normandie, vol. vi. p. 380, and vol. ix. p. 56 (1880 & 1884).

<sup>6</sup> Trans. Geol. Soc. ser. 2, vol. i. pt. i. (1822) p. 73.

<sup>7</sup> Proc. Geol. Soc. vol. ii. p. 546.

		Feet.
	{ 8. Firm greyish-white chalk, with layers of chert-nodules.....	30 to 40
	{ 7. Greyish glauconitic chalk, with cherts and hard calcareous concretions and many brown phosphatic nodules in the lower part .....	10 to 11
CENOMANIAN.	{ 6. Greyish-white or yellowish chalk, with many layers of greyish-black chert. A bed of hard, grey, shelly, glauconitic chalk occurs in the middle at St. Jouin, but dies out westward ...	70 to 80
	{ 5. Bluish-grey, sandy, and very glauconitic marl with many black phosphatic nodules .....	3½ to 6
GAIZE AND GAULT.	{ 4. Bluish-grey, sandy, glauconitic marl with layers of hard siliceous concretions .....	23 to 26
	{ 3. Dark grey, nearly black, sandy, glauconitic clay with phosphatic nodules at the base.....	10 to 11
? APTIEN.	{ 2. Coarse, brown, pebbly sandstone .....	15 to 16
	{ 1. Fine, yellow, micaceous sand.....	70

### Upper Neocomian Sands—Aptien.

The sands which form the base of the Cretaceous series at La Hève are yellowish, fine, and micaceous, easily dug with the fingers, and veined or streaked with red-brown iron oxide, which frequently cements the grains together in thin platy pieces. Near the top are some concretionary masses of ironstone.

Immediately overlying these sands, and sharply divided from them, is a bed of brown, pebbly, sandy grit, closely resembling unconsolidated Carstone. Many fragments of fossil wood occur in it; other fossil remains are rare, but M. Lennier has obtained *Ostrea aquila* and *Ammonites Milletianus*.<sup>1</sup> Like all the beds of the lower part of the Cretaceous series, it thins to the southward; its thickness nearly a mile east of Cape La Hève is 16 feet, while at Ste. Adresse, south-west of the headland, its thickness has diminished to 11 feet.

The sequence of these beds has been differently classified by French geologists at different times.

The yellow micaceous sands and the brown pebble-bed above them, Nos. 1 and 2 in our section, were first regarded by Prof. Hébert in 1872<sup>2</sup> as 'Néocomien supérieur,' which was his name for the Aptien of d'Orbigny. In 1875, however, he was inclined to range these sands with the Gault, because he had found fragments of *Ammonites Milletianus* in the sands near Octeville, and because M. Lennier had obtained fossils identified as *Ammonites Deluci*, *Trigonia Fittoni*, and *Nautilus Bouchardianus* from these sands at Havre. The two beds are so exactly the counterpart of those at the summit of the Lower Greensand in the Isle of Wight, and described in the Survey Memoir under the name of 'Sand Rock Series' and 'Carstone,' that we cannot help thinking that Prof. Hébert's first opinion was the correct one. Certainly it would be strange for the species above mentioned to occur in an Aptien sand, but M. Lennier informs us that he is by no means certain of the identification of these fossils.

<sup>1</sup> Recorded by Prof. Hébert, Bull. Soc. Géol. France, ser. 3, vol. iii. (1875) p. 516.

<sup>2</sup> *Op. cit.* ser. 2, vol. xxix. p. 449.

## The Gault and Upper Greensand—The Albien of M. de Lapparent.

Above the coarse pebbly grit comes a dark, sandy, glauconitic clay, almost black when wet, which passes up into a sandy and glauconitic marl. This is the equivalent of our Gault and Greensand, the Gault and Gaize of French geologists; there is no plane of division between them, the one gradually passing up into the other.

The lower part of this division can be conveniently seen near Ste. Adresse,  $\frac{1}{2}$  mile south-west of the lighthouses, where the following section was taken, in descending order:—

GAULT.	Dark bluish-grey, sandy, micaceous, and glauconitic clay, seen for .....	7 feet.
	Dark bluish-grey (almost black), sandy, and very glauconitic clay, containing a few light-coloured phosphates (dark internally) .....	4 feet.
	Bed of phosphatic nodules, contained in a mixture of the underlying coarse sand and the glauconitic sandy clay above .....	6 inches.
	Coarse, brown, sandy grit, containing pebbles as large as a bean .....	3 feet.
ALBIEN.	Coarse, brown, sandy grit .....	8 feet.
	Soft greyish-yellow sand was seen below this; the junction-bed, however, was not attainable .....	15-18 feet.

The bed of light-coloured phosphate-nodules intermingled with the bed below, the nodules often including small quartz and lydian-stone pebbles.

The micaceous clay of the Gault passes up into a sandy, glauconitic, micaceous, and slightly calcareous marl containing small dogger-like concretions, and as one follows it upward these concretions increase in importance and number, and finally divide the deposit into courses. At the top of the division the doggers give place to definite beds in which silica seems to saturate the deposit, forming hard courses, which alternate with courses of softer marl.

The following is a detailed section through the Gaize and Gault at a point nearly 1 mile east of the lighthouses on Cape La Hève:—

		Feet.	Inches.
GAIZE or UPPER GREENSAND.	Chloritic Marl (see p. 119) .....	6	0
	Alternating beds of blue-grey marl and beds of hard siliceous stone .....	3	6
	Dark blue-grey, sandy, glauconitic marl, containing doggers of hard siliceous stone, arranged more or less in layers .....	7	0
	A double line of doggers, separated by blue-grey, sandy marl .....	1	9
	Blue-grey, softish, sandy marl .....	1	3
	Dark blue-grey marl, with a line of large and well-separated doggers .....	1	9
	Dark blue-grey marl, with small scattered doggers, arranged more or less in lines .....	11	0
	Very dark, almost black, marly, glauconitic clay; a layer of phosphatic nodules at the base .....	10	0
	Coarse pebbly brown sand .....	16	0
	Yellow micaceous sand .....	70	0
K 2			

Like the pebbly sand, these beds diminish westward; for just south of the lighthouses the thickness of Gault and Gaize is 28 feet. M. Lennier gives the thickness of the Gault at Cauville, some 6 or 7 miles north-east of Cape La Hève, as 22-23 feet, and he divides it into three beds.<sup>1</sup> Here therefore the combined thickness of Gault and Gaize is probably about 50 feet.

Prof. Hébert<sup>2</sup> was of opinion that no actual representative of the Gault occurs at La Hève. He refers to its existence at Cauville, and states that common Gault fossils were there abundant and well-preserved. He also admits its occurrence near Octeville, where 'the bed of conglomerate is covered by a blue clay without glauconite, but containing many small pebbles of quartz and septaria, with Gault fossils.'

'At Cape La Hève,' he says, 'this bed is only represented by a layer of septaria, of pebbles, of vegetable fragments, or of fossils of the Gault, washed by the waters which brought the glauconite, and *remaniés* in the midst, and especially at the bottom of this deposit, in contact with the conglomerate.' This appears to be a description of the basal nodule-bed; these 'septaria' are doubtless what we have called phosphate-nodules.

He continues as follows:—'Je range dans cette dernière assise (Craie glauconieuse) les argiles noirâtres, très glauconieuses, avec lits siliceux intercalés, qui, au Cap La Hève, reposent immédiatement sur le poudingue à *Ostrea aquila*;' and he gives the thickness of these beds as from 16 to 20 metres (*i. e.*, 52 to 66 feet). This great thickness suggests to us that Prof. Hébert may have included in this division of the Craie glauconieuse all the beds which have a blue-grey colour, for our measurements make them 52 to 55 feet. This view receives some confirmation from his further remarks, which are:—'It is true that there occur in this series a certain number of Gault species, whose existence I do not deny, but these beds also yield a good number of the more characteristic species of the Craie glauconieuse: among Echinoderms, *Epiaster crassissimus*, *Epiaster distinctus*, *Holaster suborbicularis*, *Cardiaster bicarinatus*, which abound, the last especially, in one of the siliceous beds; among the Acephala, *Panopæa mandibula*, *Ostrea conica*, etc. It is this lower series that I have designated by the names of the zone of *Holaster suborbicularis* and *Ammonites inflatus*.'

Of the echinodermata mentioned above we found only *Epiaster crassissimus*, and that is common above bed 5. We did not find any below, and even if they did occur we cannot regard that fact as very significant. There is no doubt that our bed 4 belongs to the zone of *Ammonites inflatus*, but both M. Lennier and Prof. de Lapparent exclude that zone from the Cenomanian; and we are entirely of their opinion on this point.

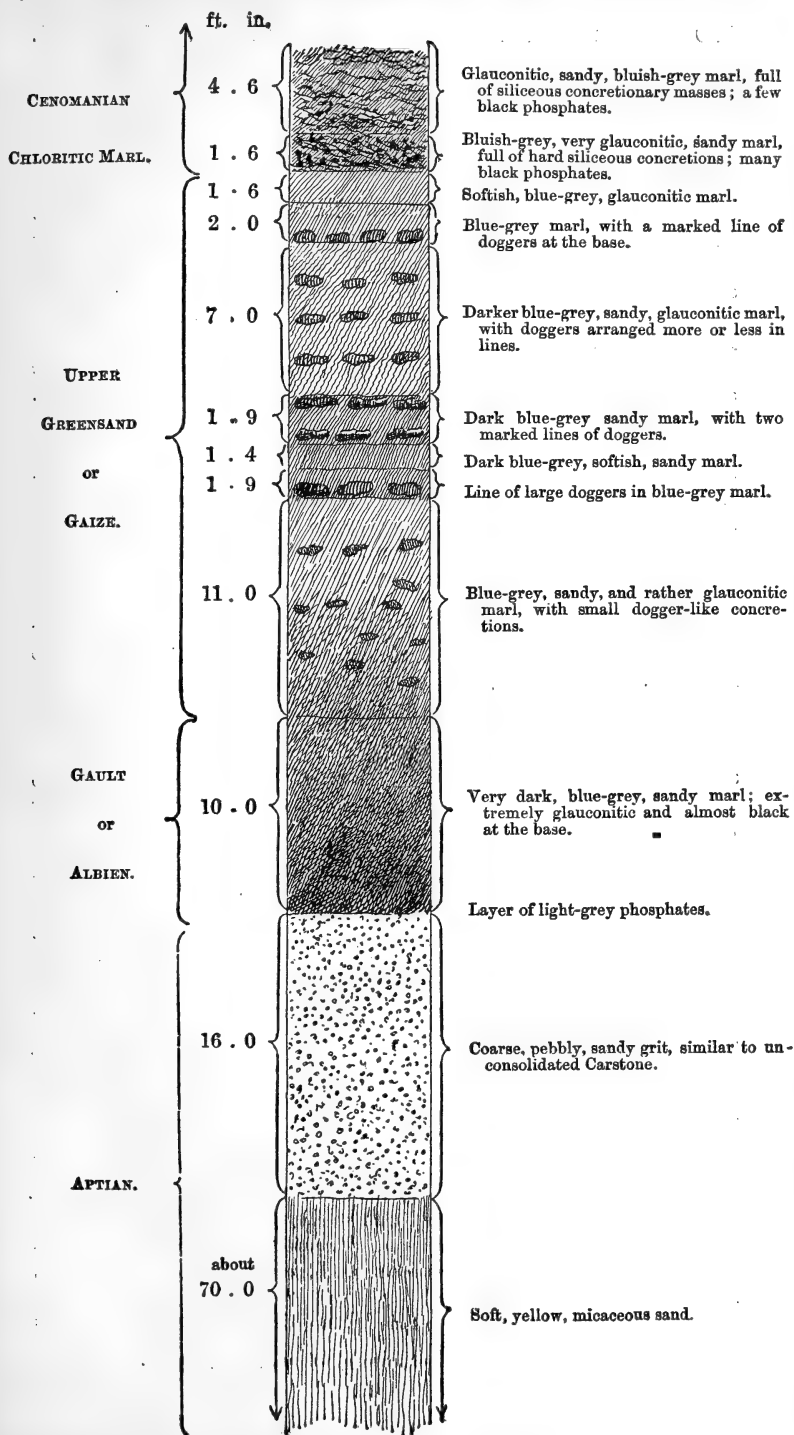
Being familiar with the lithological change which our Gault exhibits as it is traced westward, we see no reason for considering the Gault to be absent because the clay which occupies its

<sup>1</sup> Bull. Soc. Géol. Norm. vol. vi. (1880) p. 358.

<sup>2</sup> Bull. Soc. Géol. France, ser. 3, vol. iii. (1875) p. 516.

# SECTION OF THE CLIFFS AT LA HÈVE, BELOW THE CENOMANIAN.

(Taken nearly a mile east of the Lighthouses.—Scale: 1 inch = 10 feet.)



place is full of glauconite. The lower 10 feet of this series is a material which resembles the Gault at Black Ven, near Lyme Regis; it is doubtless from this 10 feet and from the overlying 23 feet of less dark and slightly micaceous marl that the Gault species have been obtained. We have, indeed, obtained *Ammonites rostratus* (var.) and *Ammonites auritus* from the upper beds in a large fallen mass at Cape La Hève. These higher beds we regard as the Gaize or zone of *Ammonites inflatus*, the representative of the Cowstone beds at Black Ven, of the Malmstone, and of the grey micaceous sands which form the lower part of the Upper Greensand in Wiltshire and North Dorset.

The Gault is poor in fossils, but we have found *Pecten orbicularis* and *Exogyra conica* just above the phosphates near Cape La Hève. The following is a list of the fossils which we found in the upper beds (Gaize) at Cape La Hève and St. Jouin:—*Holaster lævis*, *Ostrea lateralis*, *O. vesicularis*, *Avicula* (near to *Rauliniana*, d'Orb.), *Lucina Dupiniana*, *Thetis Sowerbyi*, *Avellana incrassata* (?), *Gibbula levistriata* (?), *Ammonites auritus* (typical form), *A. Raulinianus* (?) small, and *A. rostratus* (a form resembling one common in the Gaize of Devizes). In the very highest layer, just below the Chloritic Marl, *Rhynchonella convexa* and *Rh. Schloenbachi* occur.

The section on the preceding page shows the succession of the beds below the Cenomanian which form the headland of Cape La Hève.

### The Cenomanian (Bed 5).

We dissent entirely from Prof. Hébert's classification of beds 4 and 5, and agree with that of M. Lennier and Prof. de Lapparent, for there can be no question as to the exact horizon where the distinctive Cenomanian fauna sets in.

M. Lennier gives the total thickness of this division at Cape La Hève as 32·75 metres (108 feet). Our measurements give only about 90 feet from the base upwards, and although more chalk is to be seen above this, it is not well shown or easily examined. With regard to detailed measurements, our own do not quite tally with those of M. Lennier, but we differ only in such manner as may occur between persons who measure a somewhat variable set of beds at different times and at different points in a long cliff-section.

M. Lennier<sup>1</sup> has given a complete section of the Cenomanian of Cape La Hève; he divides it into 11 beds, 10 of which are seen at La Hève, the uppermost only coming in between Brunval and St. Jouin. He describes the basement-bed as a soft sandy glauconite, sometimes containing hard blocks ('roches'), with nodules of phosphate of lime perforated by lithodomous mollusca, from 1 to 2 metres thick. This bed is very rich in fossils, the commonest being *Ammonites Mantelli*, *A. varians*, *Pleurotomaria perspectiva*, *Pl. Mailleana*, *Ostrea conica*, *O. serrata*, *O. Lesueurii*, *Spondylus striatus*, *Rhynchonella compressa*, etc.

From this description there can be no doubt that he takes the

<sup>1</sup> Bull. Soc. Géol. de Normandie, vol. vi. (1880) p. 380.



base of the Cenomanian at the bed of sandy glauconitic marl, which contains black phosphates (see p. 119), and in this we entirely agree. There is here a well-marked plane of division, for the phosphate-bed is separated from the marl below by a seam of sand, full of glauconitic grains, a rich brown in the centre, from 2 to 3 inches thick. This brown sand was noticed in all the sections between Cape La Hève and St. Jouin, except at one place, about a mile east of the lighthouses. The soft marl forming the bed itself is full of glauconite, the grains being large as well as abundant; small quartz-pebbles are not uncommon, and the black phosphatic nodules are not unlike those of the Cambridge Greensand; indeed, an analysis by Berthier quoted by M. Lennier shows that they contain 57 per cent. of phosphate of lime. The following is a list of the fossils collected by one of us from this nodule-bed; a few marked L are given on the authority of M. Lennier, and we are indebted to Dr. G. J. Hinde, F.G.S., for naming the sponges and polyzoa:—

## PORIFERA.

*Trematocystis siphonioides*, Mich.

— *d'Orbigny*, Hinde.

*Corynella rugosa*, Hinde.

—, sp.

*Elasmostoma consobrinum*, d'Orb.

— *plicatum*, Hinde.

*Jerea*, sp. (= *Siphonia*).

*Pachypoteron compactum*, Hinde.

*Stauronema Carteri*, Sollas.

*Plocoscyphia* (?) fragments.

## HYDROZOA.

*Porosphaera urceolata*, Phil.

## ANNELIDA.

*Ditrupa difformis*, Lam.

*Galeolaria plexus*, Sow.

## ECHINODERMATA.

*Cidaris vesiculosa*, Goldf.

—, sp.

*Discoidea subucula*, Klein.

*Goniophorus*, sp.

*Salenia*, sp.

*Pseudodiadema ornatum*, Goldf.

— *Benettii*, Forbes.

— *variolare*, Brongn.

L *Hotaster subglobosus*, Leske.

## POLYZOA.

*Ceripora* (*Ceriacava*) *mammillaris*, d'Orb.

*Diastopora*, sp.

—, sp.

*Alecto*, sp.

*Melicertes compressa*, d'Orb.

*Sparsicava irregularis*, d'Orb.

*Radiopora* (*Domopora*) *tuberculata*, d'Orb.

## POLYZOA (continued).

*Radiopora ornata*, d'Orb.

*Micropora*, three species.

## BRACHIOPODA.

*Rhynchonella dimidiata*, Sow.

— *convexa*, Sow.

— *Grasiana*, d'Orb.

*Megerlia lima*, Detr.

L *Terebratula bicipitata*, Sow.

*Terebratella pectita*, Sow.

L *Terebrirostra lyra*, Sow.

## LAMELLIBRANCHIATA.

*Exogyra conica*, Sow.

— *Rauliniana*, d'Orb.

*Ostrea canaliculata*, Sow.

— *Lesueurii*, Sow.

— *carinata*, Sow.

*Pecten asper*, Sow.

— *Duimpliana*, d'Orb.

*Neithea quadricostata*, Sow.

*Spondylus striatus*, Sow.

*Trigonia spinosa*, Ag. (non Park).

*Cyprina*, sp.

## GASTEROPODA.

*Avellana cassis* (?), d'Orb.

*Natica* (like *gaultina*).

L *Pleurotomaria Mailleuna*, d'Orb.

— *perspectiva*, Sow.

*Turboidea*, sp.

## CEPHALOPODA.

*Ammonites Mantelli*, Sow.

— *navicularis*, Mont.

— *varians*, Sow.

*Scaphites aequalis* (a fragment).

L *Nautilus subradiatus*, d'Orb.

*Turrilites*, sp.

It will be seen that the contrast between this fauna and that of the beds below is very great. It is the incoming of an entirely new set of fossils, and the presence of *Stauronema Carteri* is a strong confirmation of the view which at once impressed itself upon us that the bed corresponds to the Chloritic Marl of the Isle of Wight. Almost all the brachiopoda and mollusca occur in our Chloritic Marl, though most of them occur also in the highest bed of the Upper Greensand near Warminster, which is part of the so-called 'zone of *Pecten asper*.' The relations of this zone in England to the French Cenomanian will be discussed in the sequel.

What we desire to point out in the present connexion is that in the cliffs near Havre there can be no question where the Cenomanian fauna commences: that it comes in suddenly with a bed which resembles our Chloritic Marl, both in its mineral composition and in its fossil contents, and in its included phosphatic nodules. Above this bed there is no break whatever, and, though the material of the overlying beds is different from that of our Chalk Marl, these beds pass up gradually into a true chalk near the top of the formation.

#### Bed 6.

At and near Cape La Hève the phosphate-bed is succeeded by beds of soft marly and glauconitic chalk, divided by layers of a peculiar kind of siliceous stone. Examination of this stone proves it to be permeated and indurated with colloid silica, the condition of the material being in every stage from merely hardened chalk to a blue-grey siliceous mass, like the immature chert occurring in the Chalk Marl of Wiltshire, and described by us,<sup>1</sup> while here and there it is concentrated into nuclei of pure crystalline silica. The result at this horizon is not definite chert or flint, but ramifying masses of siliceous material, passing in places to clear black or grey-coloured chert or flint, without any definite rind.

These beds are discontinuous, and there is a good deal of variation in the succession of chalk and chert, even in sections a short distance apart.

Between these hard beds the chalk is soft and marly, sometimes firm, but it always contains much glauconite in grains of rather small size compared with those of the Chloritic Marl. The hard beds gradually become less marked, and separated nodules or beds of chert begin to appear.

The incoming of the cherts at La Hève is marked by five courses of exceptionally massive character, and these form a striking feature in the cliff-face. A little east of the lighthouses the lowest line is 34 feet above the base of the Chloritic Marl, but nearer Havre it is only 27 feet 6 inches above it.

Above and between these cherts to the top of Bed 6 the chalk is of a pale yellowish-white colour, firm in character, and rather

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 403.

rough or gritty to the touch, and it contains less glauconite than that below.

Grey or black cherts in separated nodules continue to occur either scattered through the chalk or in lines at irregular intervals.

The bluish colour, probably due to argillaceous matter deposited with the chalk, gives place very irregularly to the yellowish-grey which is the characteristic tint of the French Cenomanian. Sometimes it extends up for 12 or 14 feet above the basement-bed, sometimes only 3 or 4 feet, and in one section near Havre the colour does not reach the Chloritic Marl.

### St. Jouin.

In going to the eastward some of the features just described as occurring at the base of the Cenomanian become lost, and the section seen at St. Jouin is somewhat different from that at La Hève. The Chloritic Marl, with the brown sandy seam and phosphates, is the same, but the succeeding siliceous beds have died out and are replaced by yellowish-white chalk containing comparatively little glauconite, and in this are lines of thin-skinned black cherts. Above this the rock for a short distance has a bluish cast.

Near the top of Bed 6 there comes in a course of grey gritty limestone, with green-coated nodules, much resembling the Totternhoe Stone of Norfolk and Suffolk. Still farther east, at Brunval, this bed thickens and is divided into two layers, separated by grey, glauconitic, gritty chalk. A marked bed of massive chert immediately beneath this can be followed by the eye from St. Jouin to Brunval.

This hard bed thins to the westward and is lost before Cape La Hève is reached. We believe, however, that the massive chert-bed which just underlies it is at about the same horizon as the five massive chert-beds at La Hève.

M. Lennier has minutely described the section seen at St. Jouin in an account published in 1884 of an excursion of the Société Géologique de Normandie to St. Jouin, Brunval, and Antifer. He makes the thickness of the Cenomanian at this point to be 118 feet 7 inches, which nearly coincides with our own measurement of 119 feet 6 inches. But his section does not appear to include the basement-bed, so that, if this be added, his estimate will be somewhat greater than ours. We here tabulate for comparison the section of St. Jouin as taken by M. Lennier and ourselves, some of Lennier's beds being grouped to save space.

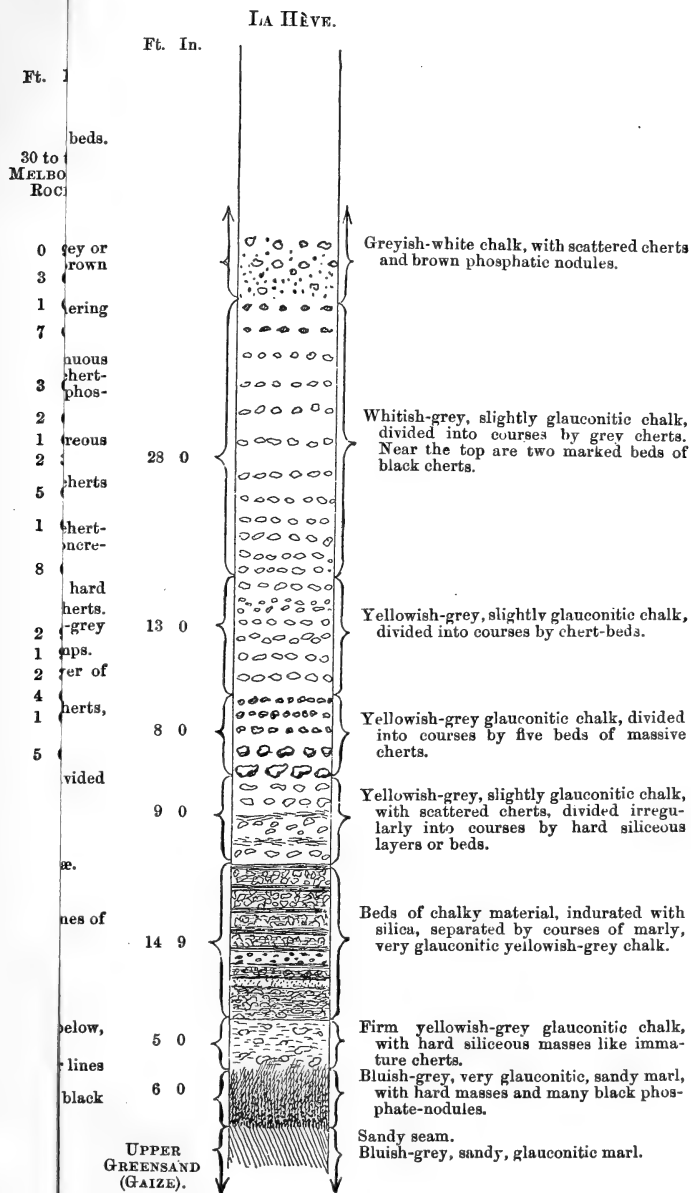
HILL, 1895.		LENNIER, 1884.	
	Feet.		Feet.
Bed 8.	Firm whitish chalk with layers of chert nodules, about.....	Compact grey chalk with nodules of bluish chert in layers .....	11½
	Greyish-white chalk divided into beds by layers of chert-nodules, bluish-grey in colour.....	Yellow or grey chalk, sandy, with layers of chert and black flint.....	26
Bed 7.	Grey glauconitic chalk, with hard calcareous masses and some cherts—many brown phosphatic nodules .....	Grey chalk with layers of cherts and many brown nodules; this bed is very fossiliferous .....	10
	Greyish-white chalk, slightly glauconitic, with layers of grey or black cherts .....	Grey glauconitic chalk with chert-nodules and layers of black flint .....	32
Bed 6.	Hard, grey, shelly, glauconitic chalk, with hard crystalline lumps and green-coated nodules .....	Hard, grey, sandy chalk in two beds with a course of sandy glauconitic marl between .....	10
	Conspicuous layer of cherts ...	Thick band of mammillated flint.	1
	Yellowish-grey chalk divided into beds by courses of chert-nodules, bands of bluish-grey chalk at intervals .....	Yellowish chalk, with irregular layers of chert and beds of grey sandy chalk .....	26
	Bluish-grey glauconitic chalk ...	Bed of large black flints .....	9 in.
	Yellowish-grey chalk with four layers of black cherts .....	Grey glauconitic chalk .....	9 in.
Bed 5. Chloritic Marl.	Bluish-grey, glauconitic, sandy marl, with black phosphate-nodules at the base .....	Siliceous bed .....	9 in.
	Thin seam of brown sand, about .....	Sandy glauconitic marl with siliceous concretions, thickness unknown.	
Bed 4. The Gaize.	Bluish-grey sandy marl, seen for 6 or 8 feet.		

We were unable to see the marly seam which is taken by M. Lennier as the summit of the Cenomanian at St. Jouin; our measurements were taken to the base of a nodular bed having the unmistakable character of Melbourn Rock. There was apparently no representative of the marl with *Belemnitella plena* at Brunval.

It will be seen, on looking at the diagram facing this page, that above the hard bed at St. Jouin, and above the massive cherts at Cape La Hève, the Chalk has the same general facies, and the same description will apply to both.

### Bed 7.

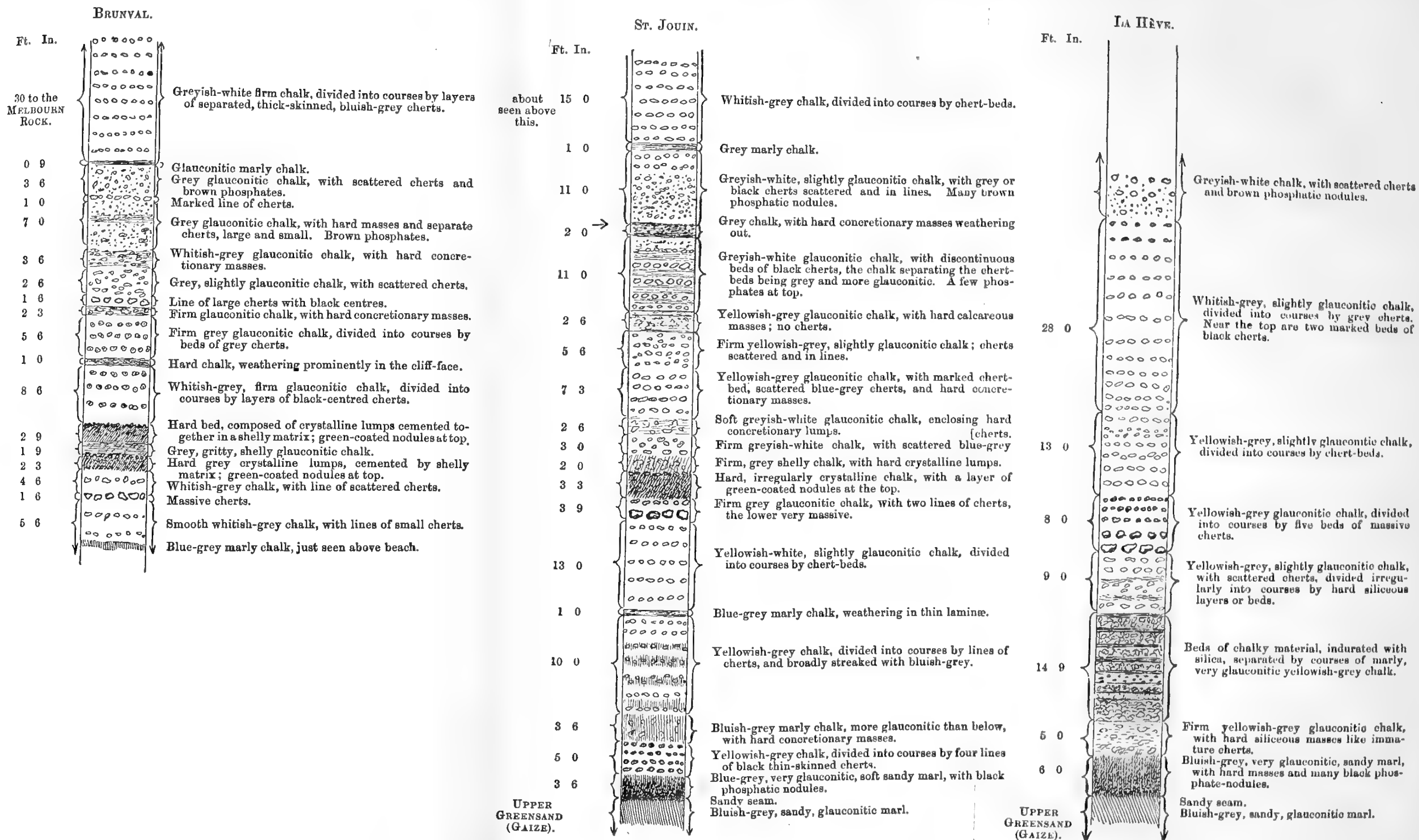
About 35 to 40 feet above the massive and conspicuous layers of chert at La Hève, and about the same distance above the marked hard bed described in the section at St. Jouin, there is a band of chalk containing many scattered phosphatic nodules of a brownish colour. These are most numerous between the chert-beds, and the chalk between them is often very glauconitic, rough and gritty to the touch. The phosphates do not occur with much regularity, and are more conspicuous at some points than at others. Beyond the fact of their occurrence there is no lithological break; they come in with chalk containing more glauconite than usual and pass away again in about 15 feet. Many fossils occur in this bed, but there





SECTIONS OF THE CENOMANIAN AT BRUNVAL, ST. JOUIN, AND LA HÈVE.

(Scale: 1 inch = 20 feet.)







is little difference between its fauna and that of the beds below. Cephalopoda are rather more abundant, but are of the same species; *Holaster subglobosus* becomes common about 8 feet below this bed and ranges above it, at the same time *Epiaster crassissimus* and *Catopygus carinatus* either die out or become rare. The following is a list of the commoner fossils occurring in this central part of the Cenomanian, the first column showing those in Bed 6, and the second those in Bed 7. The letter L indicates species which are given on the authority of M. Lennier:—

	Bed 6.	Bed 7.		Bed 6.	Bed 7.
<i>Porosphaera</i> , sp.....	*		<i>Ostrea canaliculata (lateralis)</i> ...	*	*
" <i>urceolata</i> .....	*		<i>Pecten asper</i> .....	*	*
<i>Rhynchonella convexa</i> .....	*	*	" <i>Galliennii</i> .....	*	*
" <i>dimidiata</i> .....	*	*	" <i>Marrotianus</i> .....		*
" <i>Grasiana</i> .....	*	*	" <i>Puzosianus</i> .....		*
<i>Kingena lima</i> .....	*		" <i>elongatus</i> .....	*	*
<i>Terebratula arcuata</i> .....	*		<i>Janira æquicostata</i> .....		*
" <i>capillata</i> .....	*		" <i>quinquecostata</i> .....	*	*
<i>Terebratella Menardi</i> .....		*	<i>Lima chlypeiformis</i> .....		L
<i>Caratopus rostratus</i> .....	L	*	<i>Spondylus striatus</i> .....		*
<i>Catopygus carinatus</i> .....	*		<i>Pleurotomaria Archiaci</i> .....	L	
<i>Cidaris vesiculosa</i> .....	*	*	<i>Avellana cassis</i> .....		L
<i>Holaster carinatus</i> .....	*		<i>Aporrhais</i> , sp., cast. ....		*
" <i>subglobosus</i> .....	*	*	<i>Ammonites falcatus</i> .....		L
<i>Epiaster crassissimus</i> .....	*		" <i>Mantelli</i> .....	*	L
" <i>distinctus</i> .....	L		" <i>varians</i> .....	*	*
<i>Pseudodiadema ornatum</i> .....	*	*	" <i>Coupei</i> .....	*	*
" <i>Benettie</i> .....	*		<i>Turritiles costatus</i> .....	*	*
<i>Discoidea subucula</i> .....	*	*	" <i>tuberculatus</i> .....	*	*
<i>Glyphocyphus radiatus</i> .....	*	*	<i>Scaphites æqualis</i> .....		*
<i>Salenia petalifera</i> .....	L	L	<i>Hamites</i> sp., .....		*
"    sp. ....	*		<i>Nautilus</i> , sp. ....		*
<i>Erogyra conica</i> .....	*	*			

### Bed 8.

Above the phosphates the chalk is featureless. It is, however, distinctly whiter and more free from glauconite; flint-like cherts continue to divide it into courses. Fossils are comparatively rare; we collected none from it.

### The Turonian.

The base of the Turonian is well marked between St. Jouin and Brunval by a bed of hard nodular chalk, like that which we recognize in England as the Melbourn Rock. In fallen blocks on the shore fossils common to the base of the Middle Chalk occur plentifully, such as: *Inoceramus labiatus*, *Rhynchonella Cuvieri*, *Cardiaster pygmaeus*.

#### IV. A CORRELATION OF THE CENOMANIAN DEPOSITS IN THE CALVADOS, ORNE, AND SARTHE.

##### 1. Calvados.

Having studied in detail the sections of the cliffs at and west of Cape La Hève, and having satisfied ourselves how much of the series corresponded to our Gault and Upper Greensand, and how much to our Lower Chalk, we desired to ascertain the stratigraphic relations of this combined Albien and Cenomanian series and that of the typical Cenomanian in the Orne and Sarthe.

This was a more difficult task, because no French geologist had explored the ground for this special purpose, consequently the exposures had to be sought for. Sections in the middle and upper part of the Cenomanian, such as occur near Honfleur, were of no use to us: what we required were exposures of the basement-beds, in order to judge how far the Havre equivalent of the Upper Greensand extended to the southward, and whether the base of the Cenomanian continued to present the same character as that exhibited by it at Havre.

We soon found that it did not, for the following section was seen at Moulineaux, about 2 miles S.S.W. of Honfleur, in a pit which had been recently dug in the side of a hill for the formation of a washing-place or reservoir. Descending order:—

		Feet.	Ins.
	Soil, chalk-rubble, fragments of chert and brownish clay .....	8	0
CENOMANIAN.	3. Yellowish-grey, soft, marly chalk, very glauconitic, and containing hard siliceous concretions, also many fossils: <i>Rhynchonella dimidiata</i> , <i>Rh. Grasiana</i> , <i>Megerlia lima</i> , <i>Ostrea vesiculosa</i> , spines of <i>Cidaris vesiculosa</i> .....	4	0
	2. A bed of hard masses in soft grey and very glauconitic marl, with <i>Rh. dimidiata</i> , <i>Catopygus carinatus</i> , etc .....	3	3
UPPER GREENSAND.	1. Dark grey, exceedingly glauconitic, calcareous marl, seen for .....	2-3	0

The material of Bed 2 resembles that of the Chloritic Marl of La Hève without the phosphates, the glauconite-grains being large, but the cementing-material of the hard masses proves to be calcite.

The overlying chalk is similar to that occupying the same position near Havre, its glauconitic grains being small, and we think there can be no doubt that the base of the Cenomanian was here exposed.

Passing to the valley of the Touques and proceeding by the high road leading from Pont l'Évêque to Lisieux, the next exposure noted was about 200 yards east of Les Forges, on the road leading to Blangy. Here a strong spring is thrown out, and yellowish-grey glauconitic chalk was shown just above it, while on the other side of the road a freshly-cut ditch showed grey and very glauconitic marl, but without hard lumps similar to those of the basement-bed near Honfleur.

Blangy lies in a branch of the main Touques Valley. On the southern side of this valley, along the high road leading to the village, the outcrop of the Upper Greensand was evident in many places, but no good section was seen.

On the northern side of the valley the hills are more precipitous, and there occur several small pits in the basal part of the Cenomanian. In one of these yellowish-white glauconitic chalk was seen passing down into yellowish-grey marly chalk containing much glauconite, and in a small exposure 30 yards to the west this was seen to be underlain by grey calcareous marl containing much glauconite in large grains. Farther on, several small exposures in the bank showed this calcareous marl passing down into a greensand. There was no complete section, and no hard lumps were found, but it was evident that the Cenomanian passed down through a bed of marly glauconitic chalk to the greensand. Returning to the main road, the grey marl and glauconitic junction-bed were again seen in a ditch about 3 miles north of Lisieux.

At the village of Hermival, which lies in another minor branch of the Touques Valley, the Upper Greensand was well seen, by following a newly-cleared ditch by the side of the roadway, passing up into a grey glauconitic marl, at the top of which was a bed of hard crystalline lumps between 1 and 2 feet thick; this was overlain abruptly by yellowish-grey glauconitic chalk. A small spring seemed to issue from the junction of the two beds.

About  $1\frac{1}{2}$  mile south of Lisieux, just before coming to the village of St. Martin de Liette, is an interesting exposure in a large sandpit, which shows that the Carstone-like bed at the base of the Gault, to which we have drawn attention in the section of the cliffs of La Hève, persists thus far, though somewhat attenuated. The section is as follows:—

	Feet.	Ins.
Rubble of grey chert and sandy soil .....	2	0
Very glauconitic and rather marly sand .....	2	6
Dark grey, greasy clay .....	0	9
Coarse brown pebbly grit, with much fossil wood and many light-coloured phosphates .....	7	0
White micaceous sand .....	about 40	0

The white micaceous sand is part of the 'Sables de Glos' (Corallian). On this rests the coarse brown grit, which is succeeded abruptly by the clay. We found no fossils in either, except the cast of a *Natica* in the brown grit, about 18 inches from the top; but M. Bigot, of Caen, informed us that he had found others in the same bed, and kindly sent them to us for inspection. Most of them showed a matrix of very glauconitic material, and we think that they have come from the very top of the grit (or Carstone) at its junction with the clay. Among them we could identify *Ammonites interruptus* (vars. *Deluci* and *dentatus*), *Pecten orbicularis*, *Cucullæa fibrosa*?, and a large *Cyprina* or *Cucullæa*. There was also a *Natica* in a brown matrix, like that of our own specimen. The

ammonites are sufficient to prove the bed which yielded them to be of Lower Gault or Albien age.

From Lisieux, acting under the advice kindly given us by M. Bigot, the country south-east of the valley of the Touques, in the neighbourhood of St. Paul de Courtonne and Orbec, was next explored.

At La Haute Roche, about  $\frac{1}{3}$  mile S.S.E. of Courtonne du Murdrac, the following section was seen :—

	Feet.	Ins.
Yellowish-grey chalk, slightly glauconitic, scattered grey cherts and ramifying siliceous concretions in discontinuous beds .....	4	0
Chalk similar to the above, with two beds of massive chert...	2	6
Yellowish-grey chalk, glauconitic, with scattered cherty or siliceous concretions .....	1	9
Yellowish-grey chalk, firm, slightly glauconitic, with large cherts arranged in discontinuous lines .....	10	0
Mealy, yellowish-grey, very glauconitic chalk, seen for .....	1	6

This exposure occurs in a low cliff capping the summit of a hill, and is not far from the base of the Cenomanian, which was estimated to be 12 or 15 feet lower than the bottom of this exposure. About this vertical distance glauconitic sand was well shown in the hedge-row and in the field below, the base of the Gaize being probably indicated by a spring and the boggy nature of the ground; if this surmise is correct, the Gaize and Gault cannot be much less than 30 feet thick at this point, and may be more.

The section can be followed for some little distance, but the junction-beds were not noticed.

About 300 yards S.S.E. of the church of St. Paul de Courtonne, 13 feet of whitish-grey, slightly glauconitic chalk was seen, with discontinuous lines of grey chert, and 30 yards farther on there was a course of hard, grey, lumpy chalk with many fossils, about 2 feet thick, making with the other a continuous section. The ground then dropped suddenly, forming a steep pitch, a feature constantly noticed at this horizon in many localities in Calvados, and below this it sloped gently to the banks of a brook some 50 yards away.

The soil was full of large glauconitic grains, evidently Greensand. A little farther S.E., in the next field, along the steep pitch of the ground already noticed, were many hard calcareous masses full of glauconite and of the same character as those of the junction-beds at Honfleur and Hermival, but the glauconitic grains were smaller. About  $\frac{3}{4}$  mile farther S.E., opposite the turning of the road to Orbec, many specimens of *Pecten asper* occurred in lumps of hard chalk scattered along the top of the pitch, the material adhering to them being yellowish-white, slightly glauconitic chalk, not like the basement-bed which was seen in the banks of the brook 4 or 5 feet lower.

The basal beds of the Cenomanian were again shown about 300 yards east of the Chapel of St. Julien de Mailloc, in a small pit in a field. The section was as follows :—

	Feet.	Ins.
Rubbly broken chalk and soil .....	6-7	0
Smooth glauconitic chalk in two massive beds, weathering with a peculiar mealy touch when handled .....	5	0
Rough, lumpy, grey, glauconitic chalk, hardly nodular, but lumpy, the lumps being hard, with soft mealy chalk between, very fossiliferous .....	6	6

At or near Orbec are several large pits at this horizon showing the lowest part of the Cenomanian, but without exposing the actual base. The most important is a quarry close to the railway, halfway between the stations of Orbiquet and St. Martin de Bienfaite. Nearly 40 feet of chalk is here exposed and its general character may be understood by the following section. Descending order :—

	Feet.	Ins.
Smooth, yellowish-grey, mealy chalk, rather glauconitic ...	2	6
Rough chalk, lumpy, the lumps being in a mealy matrix .	2	0
Soft, yellowish-grey, mealy chalk with grey cherts .....	7	0
Rough, glauconitic, yellowish-grey chalk with hard lumps in a softer mealy matrix .....	5	0
Firm, glauconitic, yellowish-grey chalk.....	2	0
Firm, glauconitic, yellowish-grey chalk, with hard silicified masses—not chert .....	3	0
Softer glauconitic chalk, weathering in platy pieces .....	2	6
Bed of large separated cherts .....	0	6
Firm, yellowish-grey, glauconitic chalk, smooth, without lumps .....	9	0
A course of hard, lumpy, glauconitic chalk .....	3	0
Smooth, whitish-grey, glauconitic chalk.....	1	6

Although the general character of the chalk seen in this quarry agrees with that at the same horizon in this and other localities, we are unable to correlate the various beds, and it would appear that minor peculiarities do not persist in the way that frequently happens in the English Chalk. The rock at this horizon is usually yellowish, or ochreous white, or grey in colour, slightly but irregularly glauconitic, some beds containing more glauconite than others, the grains being small. It weathers down and gives off a dust which has a somewhat gritty, mealy texture, and is not the impalpable powder which results from the handling of English chalk.

It contains many concretions of a siliceous nature, sometimes merely silicified chalk; but often there is a nucleus of clear black or grey silica, which merges through the silicified chalk into the calcareous matrix which surrounds it, there being no rind. Well-defined chert-nodules are, of course, also common.

## 2. Northern Orne.

Continuing the exploration of the Touques Valley, evidence of the outcrop of the Greensand was met with in several localities, but no section was seen until Fauvaque was reached. Here a small quarry showed Greensand still underlain by a thin bed of clay, which in its turn rested directly on the Corallian—the Carstone-like bed being absent.

A mile north of Notre Dame de Courson a new section in a road-cutting was fortunately seen, showing about 9 feet of soft, exceedingly glauconitic sand, and about 100 yards north of this the section was carried higher in the bank of a short cutting in a lane. Here there occurred about 2 or 3 feet of greyish calcareous and rather marly sand with rusty markings. It contained many fragments of *Pecten asper*, and the material was very similar to that found at the summit of the Greensand at Vimoutiers, 6 miles southward. No hard calcareous masses were seen, but we think that this grey calcareous marl was undoubtedly the top of the Greensand.

Vimoutiers was the next place of interest, and we have heartily to thank M. Lecœur, of this town, for his kindness in accompanying one of us to the principal sections in the neighbourhood, and also for his generosity in adding some named specimens to our collection of fossils. Nowhere else was the whole Cenomanian so well shown as in the large quarries near here, which give almost a complete section from the Greensand below to the Craie marneuse at the top. Besides this, continuous railway-cuttings enable one, armed with proper authority, to study the upper part of the Cretaceous series far above the beds in which we had especial interest, and one could not help regretting that time allowed the study of the basal portion only. The following section was taken at a very large quarry, nearly a mile north-east of the church:—

		Feet.	Ins.
	Soil, etc. ....	1	0
	Greyish, glauconitic, sandy chalk weathering to mealy dust, rather harder rough rock alternating with smoother layers, cherts scattered or in discontinuous lines .....	37	0
	Yellowish-grey, glauconitic, sandy chalk, rough, with hard irregular lumps (not nodules), softer chalk between .....	6	0
	Massive grey cherts, apparently a continuous bed .....	1	0
CENOMANIAN.	Yellowish-grey, glauconitic, sandy chalk, rough and lumpy, softer mealy chalk between the lumps .....	1	6
	A line of separated cherts .....	0	9
	Yellowish-grey sandy chalk, rather glauconitic, with lighter patches, massive cherts irregularly scattered—passing down to .....	6	0
	Yellowish-grey, rather soft, mealy, and very glauconitic sandy chalk containing hard siliceous concretions .....	6	0
	A bed of detached, hard, calcareous masses, very glauconitic, forming a marked hard layer .....	1	0
UPPER GREENSAND.	Greyish-green, very glauconitic, calcareous, sandy marl with rusty markings, passing down to dark green glauconitic sand, which gradually became darker and was almost black at the base .....	10	0

The Corallian immediately underlies the Greensand, but the actual junction is not seen in this quarry.

The line of separation between the Cenomanian and the Greensand is sharply marked, and the lithological difference between the two is striking. The one is a yellowish-grey, slightly glauconitic chalk, the other is a green marly sand in which large grains of glauconite preponderate, and even at the top, which is most calcareous, they give a distinct greenish tint to the deposit. This green sand is so soft that it can be dug with the fingers.

No fossils of any kind rewarded a search in the Greensand, nor was the base of the Cenomanian very fossiliferous. Many of the cherts and siliceous masses were evidently sponges, too bulky to carry away.

Most of the section given above is in the zone of *Ammonites Mantelli*; the highest part of this zone, with the overlying Craie de Rouen, or zone of *Ammonites rotomagensis*, and the Craie marneuse is seen at the quarry at Lisores, about a mile north-west of the railway-station at Vimoutiers. About 40 feet of fine-grained, glauconitic, sandy chalk of the upper part of the zone of *Ammonites Mantelli* was here exposed, with courses of rough lumpy chalk, and cherts, some scattered and some in layers.

The base of the zone of *Ammonites rotomagensis* is marked by a bed of intensely hard, creamy-yellow, crystalline, and glauconitic chalk, containing the usual hard siliceous masses of partly-formed chert. A series of small pits showed similar hard beds alternating with layers of soft grey and very glauconitic marly chalk, so soft in places that it could be almost dug with the fingers. These beds were in turn overlain by the Craie marneuse, a whitish-grey, slightly glauconitic, marly chalk not unlike in texture to the top of our own Grey Chalk.

Thus the whole succession of the Cenomanian seen at Vimoutiers is as follows, the thicknesses given being supplied to us by M. Lecœur:—

		Feet.
TURONIAN.	Craie marneuse .....	10-14
CENOMANIAN.	{ Craie de Rouen or Zone of <i>Ammonites rotomagensis</i>	33
	{ Zone of <i>Ammonites Mantelli</i> .....	113-115
	{ Upper Greensand .....	10
	Corallian.	

Many of the fossils found in the Craie de Rouen are in light brown phosphate. We recognize in this Craie de Rouen Beds 7 and 8 of the section at Cape La Hève.

M. Lecœur, of Vimoutiers, has sent us the following list of fossils collected by him from the Craie de Rouen of that locality and permits us to publish it:—

## List of Fossils from the Craie de Rouen.

<i>Catopygus carinatus.</i>	<i>Trigonia spinosa.</i>
<i>Discoidea subucula.</i>	<i>Avellana cassis.</i>
<i>Epiaster crassissimus.</i>	<i>Fusus Esparillaci.</i>
<i>Pseudodiadema variolare.</i>	<i>Pleurotomaria</i> , 2 species.
<i>Terebratula biplicata.</i>	<i>Ammonites varians.</i>
— <i>lacrymosa (ovata).</i>	— <i>rotomagensis.</i>
<i>Rhynchonella alata (=dimidiata,</i>	<i>Scaphites æqualis.</i>
Sow.).	<i>Baculites anceps?</i>
— <i>Lamarckii.</i>	<i>Turrilites costatus.</i>
<i>Ostrea pseudo-vesiculosa.</i>	<i>Hamites simplex.</i>
<i>Inoceramus cuneiformis.</i>	<i>Nautilus elegans.</i>
<i>Corbis rotundata.</i>	— <i>carinatus.</i>

In addition to these we have obtained :—

<i>Ostrea canaliculata.</i>	<i>Cardium</i> , sp.
— <i>carinata.</i>	<i>Ammonites cenomanensis.</i>
<i>Janira æquicostata.</i>	<i>Turrilites tuberculatus.</i>

The fauna really differs very little from that of the zone of *Ammonites Mantelli*, except that in this locality some of the cephalopoda, such as *Ammonites rotomagensis* and *cenomanensis* and *Scaphites æqualis*, do not occur in the lower zone. Elsewhere, however—for instance, near Havre and in England—*Scaphites æqualis* ranges to the very base of the Cenomanian.

About 1¼ mile S.W. of Gacé there is a large quarry where the Corallian has been dug; a lane leads round its southern extremity, and here there occurred a complete section through the Greensand to the zone of *Ammonites Mantelli* as follows :—

		Feet.
	Rubble of chalk, cherts, and soil.	
CENOMANIAN.	Yellowish-grey, sandy, micaceous, glauconitic, siliceous 'chalk' (more than usually rusty-coloured, probably much weathered).....	6-8
	A layer of hard, very glauconitic, siliceous, partly crystalline masses .....	1
UPPER GREENSAND.	Exceedingly glauconitic, green-grey, sandy marl, passing down to very dark, marly, glauconitic sand, almost black at the base .....	9
	CORALLIAN.	—

*Ammonites Mantelli* and *A. navicularis* occurred in the yellowish 'chalk.'

Near Mortagne, along a field-path leading from Mortagne to Villers, the Greensand was seen in several places as one passed over the outcrop, but no section was found.

Near the railway-station at Villers, in a ditch by the roadside along the road towards Fiengs, it was constantly exposed. Returning from Villers by the road which joins the high road from Paris to Brest at La Jarretière, Greensand was seen in the fields adjoining the road, and at one point the plough had turned up many pieces of the hard crystalline bed at its summit.



Turning towards Mortagne, along the high road, about  $\frac{1}{4}$  mile from the village of La Jarretière, the Greensand is exposed in a lane to the left much as it is at Gacé. Its character is the same,—a light, calcareous, marly sand, passing down to a deposit almost black in colour. The top is hidden; a wide dark band, visible for some distance away, betrays its outcrop in the arable fields, over which are scattered fragments of the hard bed. The estimated thickness of the Greensand here is 15 feet.

The yellowish 'chalk' with *Ammonites Mantelli* was seen to immediately overlie the Greensand in the cutting of the road to St. Hilaire les Montagne, about 100 yards nearer La Jarretière.

From the evidence gained by this traverse we think that after leaving Cape La Hève a lateral change takes place at the base of the Cenomanian; that the bed with black phosphates dies out before reaching Moulineaux, near Honfleur, and gives place to a bed containing hard crystalline masses; that between Lisieux and Vimoutiers this bed becomes condensed, as it were, until it forms a small and well-marked hard layer at the base of the 'Chalk.' If we are correct in this opinion, this hard layer is the true base of the Cenomanian, and the beds below ought to be excluded from this stage.

We have seen that the Gault at Lisieux is at the point of disappearance, and consequently we take the mass of the glauconitic sand south of that place to be the equivalent of the Gaize; but, as *Pecten asper* occurs in the sandy marls at the top of these, it would appear that a local or lenticular deposit representing the English zone of *Pecten asper* is present for some distance. Whether this enters into the 10 feet of glauconite at Vimoutiers we will not undertake to say, but we have no doubt that this 10-foot bed is the attenuated representative of our Upper Greensand, and that the beds above it are the equivalent of our Lower Chalk.

[Note. November 7th, 1895.—Since the above was written we find that Prof. de Lapparent has expressly separated this 'glauconie à *Ostrea vesiculosa*' of the Eure, Orne, and Maine from the Cénomanién ('*Traité de Géologie*,' 2nd ed. 1885, pp. 1041 and 1075). He classes it with the Albien, and considers it to be the equivalent of the Gaize of the Havre district; speaking of the Cenomanian of the Orne on p. 1075, he describes it as 'resting on the glauconie à *O. vesiculosa*.' This was a new departure, MM. Guillier, Bizet, and other French geologists having always regarded it as the basement-bed of the Cenomanian Series. It is satisfactory to find that we had independently arrived at the same conclusion as M. de Lapparent, and that, so far as Western France is concerned, we are in complete accord with his definition of the Cénomanién stage.

He does not venture upon any correlation of the western Cénomanién with English deposits, but includes the Warminster Greensand in his table of English equivalents. If, in his next edition, he were to omit this greensand, his table would express precisely our view of the subject.]

### 3. The Cenomanian Sands of the Southern Orne and Sarthe.

We now come to a region which has been well explored by Messrs. Paul Bizet and Albert Guillier. The great change from a chalky to an arenaceous facies begins to set in between Gacé and Mortagne, and, curiously enough, this occurs at the very top of the formation, beds of sand coming in above the 'Craie à *Ammonites rotomagensis*.' These are the 'Sables du Perche,' and it is interesting to find that they contain fossils which we are accustomed to associate with much older deposits (Chalk Marl and Upper Greensand). M. Bizet mentions, as common fossils, *Ammonites navicularis*, *Ostrea carinata*, *Rhynchonella compressa*, with many shells of *Exogyra conica* and *E. columba*.

Near Mortagne the sequence is given by M. Bizet<sup>1</sup> as follows:—

4. Sables du Perche à *Ammonites navicularis*.
3. Craie de Rouen à *Ammonites rotomagensis*.
2. Craie glauconieuse à *Ammonites Mantelli*.
1. Glauconie et argile glauconieuse à *Ostrea vesiculosa*.

The Craie de Rouen is a thick mass of chalk which is divisible into two parts or zones: (1) an upper zone of *Scaphites æqualis*, which consists of alternating beds of firm chalk and greyish marl; (2) a lower zone to which he does not assign any particular fossil, but which consists of chalk with nodules of greyish flint.

The Craie glauconieuse is evidently like that which we have described at Vimoutiers and elsewhere, but M. Bizet seems to include in it what we regard as the uppermost beds of the 'glauconie' or Greensand. Thus, in his excellent paper on the 'Profil géologique du Chemin de fer de Mamers à Mortagne,' he writes:— 'Above the greensand come more or less argillaceous marls and sands, then alternations of glauconitic sand and beds of a kind of greenish or yellowish chalk, always containing many green grains.' He classes both these in the zone of *Ammonites Mantelli*, but we did not find that fossil in the argillaceous marl, and, as already stated, for us the base of the Cénomanian is at the top of this marl and at the base of the yellowish chalk.

Near Mortagne and Bellême the lowest Cretaceous deposit is the 'Glauconie à *O. vesiculosa*.' This is a sandy marl or clay, which in some places, and especially in the east of the department, contains phosphatic nodules; its thickness is only from 3 to 10 feet, and *Ostrea vesiculosa* is the sole fossil found in it. At Ceton, however, on the eastern border of the Orne, a representative of the Upper Gault or Gaize comes in below this 'glauconie'—a glauconitic clay with phosphatic nodules and casts of fossils, among which are *Ammonites inflatus*, *A. auritus*, and *Arca carinata*. *Ammonites splendens* has also been found in the same bed at Souancé, near Nogent-le-Rotrou.

It is clear, therefore, that the Upper Cretaceous sequence in the east of the Orne is nearly as complete as in the Calvados, and that it is merely a question as to where the line for the base of the Cénomanian should be drawn.

<sup>1</sup> Bull. Soc. Géol. Normandie, vol. viii. (1881) p. 40, and vol. xi. (1885) p. 58.

## 4. Sarthe.

Proceeding still southward, we find that the next change takes place in the lower portion of the Craie de Rouen, which becomes sandy and passes into grey sands with blocks of calcareous sandstone. Thus in the communes of Théligny and Lamnay a mass of such sand is intercalated between the 'Craie à *Scaphites*' and the 'Craie glauconieuse à *Ammonites Mantelli*.' The researches of M. Bizet in this district have established the following succession:—

	Feet.
5. Sables du Perche à <i>Rhynchonella compressa</i> , with <i>Ammonites navicularis</i> and <i>Trigonia</i> .....	+20
4. Craie à <i>Scaphites æqualis</i> , with <i>Ammonites varians</i> , <i>Turritites costatus</i> , and <i>Pecten asper</i> .....	60 to 70
3. Sables et grès à <i>Perna lanceolata</i> et <i>Anorthopygus orbicularis</i>	130
2. Craie glauconieuse à <i>Ammonites Mantelli</i> , <i>Turritites tuberculatus</i> , <i>Pecten asper</i> , etc. ....	80
1. Glauconie à <i>Ostrea vesiculosa</i> .....	25
	<hr/> +325

Finally, towards the south-west, in the direction of Le Mans, the 'Craie à *Scaphites*' also undergoes a lateral change; beds of sand and sandstone set in, and the chalky marls thin out, till the whole is replaced by sands of various colours, grey, green, and yellow, enclosing large blocks of calcareous sandstone. These sands have yielded a large number of fossils, the numbers known to M. Guillier in 1886 being, of mollusca 200 species, of echinodermata 30, of bryozoa, corals, foraminifera, and sponges over 130 species. The larger number of d'Orbigny's types were in fact obtained from this portion of the Cenomanian series.

The 'Sables à *Anorthopygus orbicularis*' maintain their characters and thickness below the 'Sables à *Scaphites*,' and have also yielded many of the same fossils.

The Craie glauconieuse, however, partakes in the prevalent change, losing its calcareous ingredient, and passing into beds of fine micaceous sand and ferruginous clay, so different in appearance from Craie glauconieuse that they might have been referred to a lower horizon, were it not that they contain in places some of the characteristic fossils of the zone of *Ammonites Mantelli*, such as *Ammonites Vibrayeanus*, *A. falcatus*, and *A. rotomagensis*.

As regards the 'Glauconie à *Ostrea vesiculosa*' M. Guillier remarks:—'In the west of the department there exist beds of glauconitic material which seem to be the prolongation of these, but, as they do not contain fossils and are intimately united with the overlying beds (argile glauconieuse à minerai de fer), we have not separated them.' Clearly some further investigation of these beds is required, and we may hope that the survey of the Sarthe on which M. Bizet is now engaged will enable him to determine whether the *O. vesiculosa*-beds die out entirely, as we should think most probable, or whether some representative of them really does occur at the base of the ferruginous clays.

From the above description it will be seen that the Cenomanian, which in the Calvados and in the north of the Orne consists chiefly of calcareous and micaceous material, is, near Le Mans, wholly represented by sands with a base of glauconitic clay. M. Guillier does not give the complete sequence at Le Mans in one view, but from his account it appears to be as follows:—

	Feet.
Sables supérieurs à <i>Rhynchonella compressa</i> .....	about 54
Sables et grès ferrugineux à <i>Scaphites æqualis</i> } .....	" 230
Sables et grès à <i>Trigones</i> et <i>Perna lanceolata</i> } .....	" 30 to 50
Argile glauconieuse à minerai de fer .....	30 to 50
	About ..... 330

All these sands, and part, at any rate, of the basal glauconitic clay, are without doubt the correlatives of the Cenomanian of Cape La Hève, as defined by M. Lennier and ourselves. In other words, we do not believe that the 'Grès du Maine,' as the central group of sands has been called, includes any representative of our Upper Greensand, but that it is merely a littoral deposit of the age of our Lower Chalk. The palæontological questions raised by this conclusion remain to be discussed. Our view of the correlation of the Cenomanian deposits in the West of France and South of England is shown in the Table facing p. 172.

#### V. THE MINUTE STRUCTURE OF SOME OF THE BEDS IN ENGLAND AND FRANCE.

##### The Cenomanian of Devon.

In hand-specimens the gritty limestone which forms the base of our zone of *Ammonites Mantelli* in the Devon series, and which is known as Bed 10 of Mr. Meyer, presents on its fractured surface a coarse, granular texture, sparkling with broken quartz-grains, often as large as a pea, and with calcitic crystals; not unfrequently, however, it is smoother and more compact, and sometimes seems to include pebbles of a finer material. When thin sections are examined under the microscope the rough, coarse-grained specimens are seen to be a sand composed of shelly fragments, minute portions of what seems to have been a previously consolidated deposit, foraminifera, and a few sponge-spicules. Large quartz-grains, some angular and some well rounded, are plentifully scattered through this sand, with here and there a grain of glauconite. The whole is cemented together by a clear crystalline calcite into a gritty limestone. In other parts of the rock the matrix seems to have been formerly a fine calcareous paste, which is now in the condition of a finely granular crystalline limestone.

As a whole, the structure of the shelly fragments is obliterated in the general crystallization, and their derivation is uncertain: their general outline does not suggest the prisms of *Inoceramus*-shells,

but rather pieces of *Pecten*, fragments of the tests or spines of echinodermata, polyzoa, and perhaps coral.

Foraminifera are not uncommon, the genera represented being chiefly *Textularia*, *Cristellaria*, and *Rotalia*; *Globigerina* is rare or absent, and calcareous 'spheres' do not occur at all. Although free sponge-spicules are uncommon, there is much sponge-structure (? of calcisponges).

#### *Bed 11.*

Bed 11 resembles the finer and more shelly portions of Bed 10, and specimens from Hooken Cliff, Beer Head, and elsewhere present the same character. Like Bed 10, it consists of calcareous particles derived from various sources, foraminifera, sponge-spicules, with many quartz- and glauconite-grains, the latter being more common than in Bed 10. The whole is cemented together by crystalline calcite.

#### *Bed 12.*

This bed is a dense, hard, crystalline limestone, with smooth fracture, containing many grains of quartz and glauconite, those of glauconite being still more abundant than in Beds 10 and 11.

Examination of thin slices proves it to be a true chalk, having a matrix of fine, amorphous, calcareous matter, now converted into granular calcite, in which are scattered a few shelly fragments, foraminifera, and some sponge-spicules. Spheres are common—the general aspect being that of certain specimens of Chalk Marl or Grey Chalk. But the rock in other parts contains many coarse shelly fragments and large glauconitic grains; these areas, though well defined, are not sharply marked off, and seem to be integral portions of the rock.

#### *Bed 13. Hooken Cliff.*

The structure of Bed 13 seems to vary at different places, but more examples are necessary to make sure of this point. The type may be taken as the marked zone of *Belemnitella plena* at Hooken. Here the matrix consists of fine amorphous calcareous matter and minute calcitic crystals. A few coarse fragments occur which can be identified as shell, and spheres and small-sized foraminifera are common. The feature of the rock is the abundance of large angular and rounded quartz-grains, and large grains of glauconite. The whole is loosely compacted, and forms a friable gritty stone.

The lower part of this bed has a somewhat different aspect. It is a compact glauconitic chalk, full of quartz-grains and coarse shelly fragments; variety of structure in the latter indicates derivation from various sources. A specimen supposed to be 13, from between Lyme Regis and Pinhay, shows a structure which approximates to that of Bed 14—the glauconitic base of the Middle Chalk

### Base of the Middle Chalk.

Specimens from Lyme Regis, Bindon, Beer Head, and Branscombe show that the usual change takes place, and that the compact glauconitic chalk at this horizon consists chiefly of spheres thickly packed in the fine calcareous material of the matrix. *Globigerinae* are among the most common foraminifera, but are not very abundant, and the shelly fragments consist chiefly of *Inoceramus*-prisms. Large quartz- and glauconite-grains still characterize the deposit, but they pass away in about 3 feet, and the rock has then the usual characters of Middle Chalk.

### The Upper Greensand (or Gaize).

#### Cape La Hève.

For the purposes of this paper it is only necessary to describe the minute structure of the upper part of the Upper Greensand (the Gaize) in order to show that the material of which this division is composed differs considerably from that of the overlying Cenomanian.

Viewed under the microscope in thin sections, the matrix of the Greensand is seen to consist largely of fine, amorphous, siliceous matter, probably silicate of alumina, intermingled with which are minute calcareous particles. There are very few foraminifera, and not many shell-fragments or sponge-spicules. Globules of colloid silica are present, but not abundant. The proportion of quartz-sand is large, but the grains are small and angular; mica-flakes may be recognized. Rather large grains of glauconite are common, but not abundant. The rock compares well with a specimen of the upper part of the Upper Greensand of the Isle of Wight, taken from Culver Cliff, except that the grains of quartz and glauconite are distinctly larger.

#### Isle of Wight.

At the top of the Upper Greensand grains of glauconite become very abundant, and these and the quartz-grains are coarser, and the rock more calcareous. Specimens from Beds 2, 4, and 5 (see p. 105) from Collins Point show distinctly the commencement of a transition from Upper Greensand conditions to those of Chalk Marl.

### The Cenomanian of France.

#### The Chloritic Marl of Cape La Hève.

The bed containing many black phosphates, which we take as the equivalent of the Chloritic Marl, will not compare in its minute structure with that of the Isle of Wight. It is a less calcareous deposit, it contains more fine inorganic material, and the grains of quartz and glauconite are more numerous and larger; indeed, as already mentioned on p. 121, some of the former are small pebbles. There is a little colloid silica, but few sponge-spicules, shell-fragments, or foraminifera.

The rock, as a whole, when viewed in thin section under the microscope, resembles more nearly the Cambridge Greensand than any of our specimens of Chloritic Marl.

*Bed 6.*

Seen from a short distance, the yellowish-white chalk into which the Chloritic Marl quickly passes, and which forms the major part of the Cenomanian in the cliffs between St. Jouin and Cape La Hève, looks like the rock we are accustomed to see on this side of the Channel; but a striking difference is seen in the lines of massive cherts which occur at irregular intervals from near the base to the summit.

A more critical examination shows that the lower part of the Cenomanian, all that included in Bed 6, possesses peculiarities not found in the Chalk of England. These are comparative lightness in the hand, a certain amount of gritty mealiness to the touch; and it is everywhere speckled by glauconitic grains, and a few minute mica-flakes sparkle on its fracture.

These peculiarities extend through Bed 6, and then there is a gradual passage to that white pulverulent limestone with which we are familiar.

When a thin section of Bed 6 is examined under the microscope, the matrix is found to be made up partly of fine, amorphous, calcareous matter, mixed probably with a small proportion of fine inorganic material, and partly of calcite in the condition of definite though minute crystals. The rock is full of shelly fragments, the derivation of the larger part of which is uncertain, but prisms of *Inoceramus*-shell are clearly less numerous than in shelly English chalk; such fragments as show structure are more frequently those of *Pecten* or portions of the spines or tests of echinodermata.

Foraminifera are present, but are not very numerous, the forms most in evidence being *Textularia*, *Cristellaria*, and *Rotalia*; *Globigerina* is rare, and spheres do not occur at all.

Intermingling with these calcareous elements are many sponge-spicules whose silica is invariably in the colloid state. These are sometimes closely packed, sometimes widely separate, but they are always present in greater number than in any English Chalk, except, perhaps, selected specimens of siliceous Chalk Marl.

Permeating the whole mass in single globules or aggregations of globules, is a large amount of colloid silica.

Glauconitic grains of large size, compared with those of our Lower Chalk, are seen in all specimens, sometimes in great abundance, and glauconite may also be seen infilling the spicular canals and the chambers of foraminifera.

Quartz-grains are common, but the quantity varies much in different specimens; they are everywhere more numerous and larger than in the English Chalk Marl, and some are angular.

This general description will apply to the whole of Bed 6 between St. Jouin and Cape La Hève. Sometimes the fine material preponderates, there are fewer quartz- and glauconite-grains, and the

chalk has a correspondingly denser texture. In other specimens, especially where sponge-spicules are numerous and there is much colloid silica, the fine and denser material seems to be in isolated grains or patches, and the rock has a granular aspect on its fractured surface. These grains seem to consist of fine calcareous material cemented by colloid silica or amorphous siliceous material.

The structure of the rock, then, somewhat resembles that seen in Beds 10 and 11 of the Devon Cenomanian, namely, separated calcareous fragments cemented together. The similarity is even carried further by the absence of *Globigerinae* and 'spheres,' and by the comparative rarity of *Inoceramus*-prisms, while shelly particles, whose derivation is uncertain, abound in both deposits.

The differences between Bed 6 of La Hève and Bed 11 of the Devon series are the abundance of sponge-spicules and colloid silica in the former, and the greatly superior size of the glauconite- and quartz-grains in the latter. Moreover, the rock of Bed 6 never becomes a crystalline limestone, and is usually in a condition which admits of its particles becoming readily detached.

Hard beds and semi-crystalline lumps do occur, especially at St. Jouin, but nothing in the specimens we brought home, either from this locality or La Hève, completely parallels the granular structure of Beds 10 and 11 of Devon; in one from Vimoutiers, however, this structure is almost exactly reduplicated.

The presence of so much quartz and glauconite, the abundance of sponge-spicules, and the absence of *Globigerinae* and spheres seem to show that this part of the Cenomanian was laid down in shallower water and nearer a coast-line than the English Chalk Marl.

### *Beds 7 and 8.*

From near the base of Bed 7 the rock passes to a deposit which we may compare with our Grey Chalk. It consists of the usual amorphous calcareous matter, in which are scattered small shell-fragments, a few calcareous spheres and foraminifera. *Globigerinae* continue rare. Sponge-spicules occur, but are less numerous, and there is little or no colloid silica. The Chalk at this horizon differs from its English equivalent in the presence of sponge-spicules, and in the occurrence of grains of glauconite and quartz. It is true that minute particles of both these minerals are to be seen far up in the Grey Chalk in the neighbourhood of Warminster and Devizes, but neither are found commonly in the Chalk of the Isle of Wight, which approaches most closely (so far as distance is concerned) to that of Cape La Hève.

Specimens taken from the base of the Turonian at Brunval show that the Chalk at this horizon is full of 'spheres' and *Inoceramus*-prisms, and is similar to that at the base of our Middle Chalk.



## Calvados and Orne.

South of the Seine we confined our examination of the lithological characters of the Cenomanian to Beds 5 and 6. In this direction we saw nothing corresponding to the 'Gaize,' and where the top of Bed 4 was exposed the material was a soft and exceedingly glauconitic sand. A specimen from Bed 5, near Honfleur, compares with the base of Bed 6 at La Hève rather than the Chloritic Marl (Bed 5), except that it contains so many large glauconitic grains, quartz-grains being in rather small quantity. Neither do sponge-spicules or colloid silica occur commonly in this specimen. The cementing-material of the hard lumps found in this bed is crystalline calcite.

Southward of Honfleur we find a steady increase in the amount of quartz-sand and organic silica in Beds 5 and 6.

Thus, at Blangy, the matrix of a specimen from 10 or 12 feet from the base of the Cenomanian consists—judging by the eye—of at least 50 % of globular colloid silica, and the amount of sand-grains (quartz) mingled with this is greater than in any specimen from La Hève. Mica-flakes can also be recognized, and among the sand are grains other than those of quartz. Glauconite is present as usual, there are a few shell-fragments and much amorphous calcareous matter; sponge-spicules are common.

Specimens from Orbiquet taken at a higher horizon, one about 20 feet and another from about 45 feet above the base of Bed 6, show a similar increase in the amount of colloid silica and terrigenous material, the relative proportion of this decreasing upwards.

We regret that we omitted to secure a series of specimens from Bed 6 at Vimoutiers. Our knowledge of the minute structure of the Chalk here is obtained from that adhering to our fossil specimens, their height from the base of the bed being uncertain. Such specimens show that the conditions noted at Orbiquet continue to this point without much alteration.

One specimen showing a structure somewhat similar to that of Bed 11 has already been alluded to.

Still farther south we find that the base of Bed 6 has completely changed from a calcareous to a siliceous rock, comparable with the Malm of our Upper Greensand.

At Gacé, in the hard bed at the base of the Cenomanian, the equivalent of Bed 5 at Cape La Hève, the cementing-material is not calcite but silica, derived probably from the abundant spicules in the deposit, and much of this silica has passed from the colloid to the chalcedonic condition. The so-called 'Craie' which overlies the basement-bed is so completely siliceous that the reaction in acid is of the slightest, while at still higher horizons the deposit is not a chalk at all, but a sandy, micaceous, glauconitic, calcareous silt, with many sponge-spicules, amongst which the reniform spicules of *Geodia*<sup>1</sup> are common.

<sup>1</sup> Identified by Dr. G. J. Hinde.

Hence it is not surprising that the fauna of the French Cenomanian should differ considerably from the fauna of the Lower Chalk, although we firmly believe that they existed contemporaneously.

## VI. CRITICAL REMARKS ON SOME OF THE FOSSILS.<sup>1</sup>

The preparation of the following lists of fossils has involved a considerable amount of critical work, in which we have been greatly assisted by Mr. C. J. A. Mejer, F.G.S., and Dr. G. J. Hinde, F.G.S. Mr. Mejer has collected and studied the fossils of the Devon cliffs for the last twenty-five years, and has bestowed much time and care upon the identification of the various species of echinoidea and mollusca. The differences between the lists of these classes of animals now given and those in his paper on the Beer Head sections (Quart. Journ. Geol. Soc. vol. xxx. 1874) are chiefly due to his own researches, the results of which he has generously communicated to us. They have resulted in some corrections and in many fresh identifications among the fossils in his unequalled collection. Some of the specimens in this collection have already been figured by Lycett and Davidson in the publications of the Palæontographical Society, and many others are awaiting the preparation of other special monographs.

To Dr. Hinde we are indebted for examining, and naming so far as possible, all the sponges, hydrozoa, and polyzoa collected by ourselves in Devon and in France.

In order to explain the appearance of certain names in the lists of fossils, we have thought it desirable to set forth the results of these combined investigations and to make some critical remarks on those species which are interesting, either from their being unknown in England or from our having found a difficulty in identifying them. In several cases also we have been able to determine the identity of English and French species which had previously borne different names, and we think that such *rapprochements* will be welcomed on both sides of the Channel.

### Sponges.

STAURONEMA CARTERI, Sollas, Ann. Mag. Nat. Hist. ser. 4, vol. xix. (1877) pls. i.-v.

This fossil was first found by one of us in the so-called 'Upper Greensand' above the Gault at Folkestone in 1876, and was recognized by Prof. Sollas as a new and peculiar form. In describing it, however, he stated that it occurred in Gault and Upper Greensand, having understood that the original specimens came from the Folkestone Gault, and possessing a specimen from the Isle of Wight which he believed to have come from the Upper Greensand.

We think that the latter must have come from the Chloritic Marl of the Isle of Wight, in which the fossil is common, while we have never seen one from the Upper Greensand. We agree with

<sup>1</sup> Mr. Jukes-Browne is responsible for this section of the paper.

Mr. F. G. H. Price in regarding the glauconitic sand above the Gault at Folkestone as Chloritic Marl, not Upper Greensand. We have also found *St. Carteri* in the Chloritic Marl with phosphatic nodules near Devizes and Warminster, and Dr. Hinde informs us that it occurs at the same horizon at Eastbourne and Selborne. It is clearly, therefore, a fossil especially characteristic of this horizon, though it may possibly range a few feet up into the Chalk Marl.

We are also informed by Dr. Hinde that there are specimens in the British Museum from La Hève, and we are now able to say that it is common there in what we regard as the equivalent of the Chloritic Marl, namely the basal bed of the Cenomanian, and in the bottom of the overlying bed, but at no higher horizon.

### Echinodermata.

#### GONIOPHORUS, sp.

A small specimen from the Chloritic Marl, which has all the characters of this genus, but differs from *G. lunulatus* in several respects. The apical disc, instead of being in low relief with a large aperture or periprocte, has its edges raised into rough tubercular ridges, which, with the similarly raised edges of the periprocte and a set of transverse bars or carinæ, make a curious pentangular pattern in five compartments surrounding the periprocte. These ridges are not plain and straight, as in *G. lunulatus*, but curved, so that the outline of the pentagon is irregular.

The test is less elevated than in *G. lunulatus*; there are only four tubercles in a row on the interambulacral areas, and the lower tubercles are very small, there being only three large ones on each area. The ambulacral areas are very prominent, and swell out towards the mouth.

Whether this is more than a very aberrant variety of *G. lunulatus* must depend on the discovery of others with the same characters; but it differs so much from the types figured by Cotteau and Wright that we felt the desirability of calling attention to it.

#### CODIOPSIS DOMA, Ag.

This sea-urchin has not previously been found in England, and, as it is specially characteristic of the Cenomanian of the Sarthe, its occurrence in Devon is interesting. The determination is due to Mr. C. J. A. Meyer, in whose cabinet the only known English specimens are. M. Bizet having kindly sent us two specimens of the large inflated form of the species, we forwarded these to Mr. Meyer, who reports that his are quite small in comparison. Probably they belong to the variety *C. pisum* of Desor.

HEMIASTER BUFO, Desor, in d'Orb. 'Pal. Fr. Terr. Crét.' vol. vi. p. 227, pl. 873.

This is a common species in the North-west of France. It is especially abundant at Blangy, Vimoutiers, and Villers-sur-Mer, but

no specimen came to hand from Cape La Hève, though d'Orbigny quotes it from there. It is a well-marked species, much more elevated than *H. minimus*, the anal area being very high and rising almost vertically from the base.

We have not seen anything like this species in England, and Mr. Mejer informs us that the *Spatangus bufo* of his Devon list in 1874 was a mistake, a better specimen having enabled him to identify it as *Hemiaster Morrisii*. Mr. Sharman, to whom we sent specimens, compared them with all the Cretaceous Hemiasters in the Jermyn Street Museum, and did not find any resembling them.

HOLASTER SUBORBICULARIS, Brongn., figured by d'Orbigny, 'Pal. Fr. Terr. Crét.' vol. vi. p. 93, pls. 814 and 815. *Hol. suborbicularis*, Wright, 'Brit. Cret. Echin.' Pal. Soc. Monogr. p. 314, pl. lxxiv. fig. 1.

We do not think that the figures above referred to represent the same species. D'Orbigny's figure is that of a rather large cordiform urchin, much resembling *Cardiaster fossarius*. He describes it as specially characterized by the bulging out of the under surface in the hinder part, so that its greatest height is in this posterior region. Moreover it has a depressed anal area, and the vent is small and placed in the upper part of this area. The anteal sulcus is rather deep.

Dr. Wright's figure does not show these characters; there is no such marked anal area; the vent is large and not very high up. There is no such prominent basal protuberance. The test is very different in shape, and is very much smaller. He himself says that 'the English specimens are small and resemble the urchin described as *Holaster cenomanensis*, d'Orb., which, however, is only a small variety of *Hol. suborbicularis*.' He also states that it occurs plentifully in the Chalk Marl and in its glauconitic basement-bed.

This last statement is incomprehensible to us, as we have collected largely from these beds, but have seen very few specimens that will compare with Wright's figure of *Holaster suborbicularis*, and none like d'Orbigny's figure. Moreover, in Dr. Barrois's well-known 'Researches in the Cretaceous Formation of England' we find only one mention of *Holaster suborbicularis*(?), and this is from the Upper Greensand.

Mr. Mejer informs us that he has some specimens from Bed 11 in Devon which agree with Wright's figure and a few which come near to that of d'Orbigny. We have therefore admitted both forms into our list.

#### HOLASTER, sp.

One of the commonest echinoderms in the zone of *Ammonites Mantelli* on the Devon coast is a form which differs from any yet described. A single specimen might be taken for a small elevated and oval variety of *Holaster subglobosus*; but, as that species occurs in the same beds and exhibits individuals of all ages, this form is either a different

species or a well-marked and unusual variety of that species. It is generally rather over an inch long and rather less than an inch broad, and about  $1\frac{3}{8}$  inch high. It is inflated below, and the vent is placed high. The anteal sulcus is bounded on each side by a ridge, which swells out near the top and gives a peaky character to this part of the test.

Mr. Sharman informs us that it comes nearest to a specimen in the Museum at Jermyn Street from the Middle Chalk of Dover, to which Prof. Forbes attached the MS. name of *Cardiaster Cockburni*.

*Pygurus Lampas*, De la Beche, Wright, 'Cretaceous Echinodermata,' p. 258, pl. lviii. fig. 1.

The original specimen of this sea-urchin was found by Sir H. De la Beche near Lyme Regis in what he took to be Upper Greensand; but as it has never been found again in the Upper Greensand of Devon, and as Mr. Meÿer has obtained a specimen from his Bed 10 at Dunscombe, it probably came from the same horizon near Lyme Regis. Many of the blocks on the shore west of Lyme consist partly of the topmost bed of the Greensand and partly of the quartziferous grits (Beds 10, 11, 12), and De la Beche might well have regarded the whole mass as Greensand, for what looks like the base of the Chalk succeeds No. 12 (see p. 111).

This species is occasionally found in the Cenomanian of Le Mans, and also occurs at Fouras in the Charente Inférieure; it is therefore a conspicuous link between the Cenomanian of Devon and Western France.

*Salenia Clarkii*, Forbes, in Wright, 'Cretaceous Echinodermata,' p. 177, pls. xxxviii., xxxix., & xlii.

A large *Salenia* occurs in the lower part of the Devon Cenomanian Bed 11, and again in the highest bed (13). It comes nearer to *S. Clarkii* of the Lower Chalk of Dover than to any other figured species, though it does not quite agree with Dr. Wright's type. A large specimen measuring more than an inch in diameter has been deposited in the Museum at Jermyn Street.

*Salenia Petalifera*, Ag., var.

Some of the specimens referred to this species also differ in some respects from the type, and somewhat resemble *S. scutigera*, Gray. The zone of small tubercles on the interambulacral areas is very narrow and sinuous, and the apical plate exhibits some characters which, if constant, would differentiate it from *S. petalifera*.

## Polyzoa.

*Ceriodava ramulosa*, Mich., sp., 'Icon. Zoophyt.,' and d'Orbigny, 'Pal. Fr. Terr. Crét.' vol. v. p. 1017, pl. 788. figs. 11 and 12.

This is a large coral-like organism, branching dichotomously, often 4 or 5 inches in length, and consisting of a number of con-

tiguous angular tubes which radiate outward and upward from a central axis. It is a very abundant fossil in the basal part of the zone of *Ammonites Mantelli* in Devon, especially at Dunscombe, Weston, and at Beer Head.

Specimens having been sent to Dr. G. J. Hinde, he reported that they strongly resembled the *Chatetes ramulosus* of Michelin found in the Cenomanian of the Sarthe. Subsequently M. Bizet, of Bellême, sent us a specimen found at Condrecieux (Sarthe), which appeared to be the same fossil. Dr. Hinde informs us that d'Orbigny placed Michelin's species as a polyzoan under the name of *Ceriocava ramulosa*; but he thinks that when the specimens are more carefully examined it will be found generically distinct from *Ceriopora* or *Ceriocava*.

In Morris's 'Catalogue' (2nd ed. 1854, p. 120) it is placed under *Ceriopora* and said to occur in the Greensand of Faringdon.

#### DEFRANCIA (PELAGIA) EUDESII, Mich.

This is another remarkable fossil, having a wonderful resemblance to a small expanded cup-coral; but it was recognized by Dr. Hinde as the polyzoan above named, which Michelin describes as common in the 'Craie chloritée' of Vaches Noires and in the 'Grès vert' of Le Mans. Only one specimen has been found in the lowest layer (Bed 10 of Meÿer) of the *Mantelli*-zone near Branscombe.

#### MICROPORA.

The two species of *Micropora* entered in the list of Devon fossils, and numbered 4 and 5 respectively, are recognized by Dr. Hinde as occurring also among the specimens collected from the Chloritic Marl near Cape La Hève, although he is at present unable to identify them as described species.

#### Brachiopoda.

##### RHYNCHONELLA DIMIDIATA, Sow., and RH. ALATA, Brong.

In Guillier's 'Géologie de la Sarthe' (1880), and in some of M. Bizet's papers on the geology of the Orne and Sarthe, we find *Rhynchonella alata*, Lam., stated to be a common Cenomanian shell; but Davidson ('Brit. Cret. Brach.' vol. i. p. 82) mentions that MM. d'Orbigny and Deshayes agree with him in considering the *Rh. alata* of Lamarck as merely a synonym of *Rh. vespertilio* of Brocchi.

Later, in his 'Supplement,' when discussing *Rh. dimidiata*, Davidson states that the names *alata* and *gallina* were given by Brongniart to symmetrical forms of this shell, and *dimidiata* by Sowerby to the unsymmetrical form. It is therefore the *Rh. alata* of Brongniart, and not of Lamarck, which is the common Cenomanian shell.

Both varieties are very abundant in the Cenomanian of Devon,

and we have compared them with a number from different localities in France. There is no doubt about the identity of the English and French forms, and it is desirable that Sowerby's name should be recognized in France as it is in England and Germany. *Rh. convexa*, Sow., also occurs in the French Cenomanian.

*RHYNCHONELLA WIESTII*, Quenst. (1871), and Davidson (1874), in Supplement to 'Brit. Foss. Brach.' p. 66, pl. viii. fig. 31.

The shells referred by Davidson to this species are very common in Bed 13, the sandy chalk which overlies the zone of *Ammonites Mantelli* in Devon. It is a much more variable species than Davidson seems to have supposed, for he describes it as having 'about 30 or 32 rounded ribs,' and adds that it approaches most nearly to *Rh. Graciosa*, 'of which it may perhaps be a large variety.'

Having collected many specimens from this bed wherever it is found, we cannot agree with Davidson. The shell seems to us much more closely allied to *Rh. Cuvieri*, from which it can only be distinguished by having, as a rule, fewer and larger ribs. The average number seems to be 24 or 26, but there are forms which have as few as 18 and others which have as many as 30; the former resemble *Rh. Mantelliana*, except that the ribs are not angular, and the latter come so near to the broader varieties of *Rh. Cuvieri* that, when placed beside them, they are indistinguishable.

Although both the names *Cuvieri* and *Mantelliana* have been admitted into our list, we believe the specimens so named are extreme varieties of one species, which may be called *Rh. Wiestii*, and may be regarded as the ancestor of *Rh. Cuvieri* and *Rh. reedensis*, Eth., which occurs still higher in the zone of *Holaster planus*.

*TEREBRATULA TORNACENSIS*, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. p. 316, pl. xviii. fig. 3, and varieties figs. 4-5.

This species was founded on specimens from the Tourtia of Tournay, and as this deposit is now known to be the littoral facies of the Cenomanian in Hainaut, and of later date than the zone of *Ammonites inflatus*, the occurrence of Tourtia forms in the Cenomanian of Devon and Sarthe is not surprising.

When Davidson first described the Faringdon fossils in 1852 he identified certain forms as *T. tornacensis*, var. *Roemeri*, d'Arch., though he was evidently for some time in great doubt about them (see 'Brit. Cret. Brach.' vol. i. p. 62). At that time he imagined that the Faringdon Sand was of Upper Greensand age, and, as the Tourtia was then supposed to be a sort of combined Lower and Upper Greensand, he saw no reason why a Tourtia species should not occur at Faringdon.

It seems, indeed, to be a fact that some of the forms of *T. depressa* and *T. tornacensis* occurring in the Tourtia are practically indistinguishable from varieties of *T. depressa* and *T. sella* which occur in the Lower Greensand of England; but the typical form of *T. torna-*  
Q. J. G. S. No. 206. M

*censis* is certainly different from the typical *T. sella*, so that it is only the smaller varieties and the distorted forms which resemble one another.

Subsequently ('Supplement,' 1874, pp. 35, 36), and after correspondence with Mr. Meÿer, Davidson was led to alter his opinion so far as to admit that the forms previously attributed to *T. tornacensis* were really only varieties of *T. sella*.

We agree with Mr. Meÿer in regarding *T. tornacensis* as essentially a Cenomanian species, and we are able to state that it occurs in the typical Cenomanian of Le Mans, where it seems to have been confused with *T. biplicata*. M. Bizet has sent us three specimens under the latter name which in the opinion of Mr. Meÿer and ourselves are typical *T. tornacensis*, differing from *biplicata* by the very characters pointed out by d'Archiac.

In Devon a few specimens have been found by Mr. Meÿer in the beds described by him as 11 and 12 at Beer Head.

Whether the real *T. biplicata* occurs near Le Mans as well as *T. tornacensis* we have no means of knowing, but it does not seem to occur in Devon and it does not occur in the Tourtia of Tournay; it is common in the Chloritic Marl of the Isle of Wight, and occurs in that of Havre, as well as at Orbiquet (Calvados) and Vimoutiers (Orne).

#### TEREBRATULA ARENOSA, d'Arch., *op. cit.* p. 324, pl. xxi. figs. 1-3.

This is another Tourtia form recognized by Mr. Meÿer in the Devon Cenomanian. It is a small globose species, the surface of which bears scattered granules or small tubercles with depressed summits, so that they resemble minute craters. It might easily be passed over as a globose form of *Megerlia lima*.

#### TEREBRATULA VERNEUILII, d'Arch., *op. cit.* p. 326, pl. xx. fig. 4.

This shell is not likely to be mistaken for any other species, as it bears a very remarkable ornamentation on both valves. They display a series of short, strong ridges, arranged in concentric rows and separated by oval indentations or hollows, so that the shell seems covered by a raised crochet-work pattern. The hollows are deepest at the top, and those of one row lie below the ridges of the row above. In the adult shell these ornamental ridges die away towards the edge of the shell.

Mr. Meÿer has found this form in the same bed at Beer Head as that which contains *T. tornacensis* and *T. arenosa*.

#### TEREBRATULA CAPILLATA, d'Arch., and *T. squamosa*, Mantell.

We think that there is a much closer connexion between these two species than has hitherto been supposed. In discussing the relations of *T. capillata* Davidson only distinguishes it from *T. depressa*, to which d'Orbigny had imagined that it had some resemblance; and in describing *T. squamosa* he does not mention *T. capillata*. Yet



it is only necessary to look at plate v. of his Monograph, where both shells are figured, to see how nearly they approach one another through the least lamellose variety of *T. squamosa* (fig. 11).

Davidson says that *T. squamosa* is very common in the 'Craie chloritée of Rouen'; it may be so, but in the middle of the 'Craie glauconieuse of St. Jouin' we find a form which is quite destitute of squamose ridges, and is ornamented with nearly straight but, slightly undulating, capilliform striæ. Except that it is of small size, it agrees more closely with d'Archiac's figures of *T. capillata* (Mém. Soc. géol. Fr. ser. 2, vol. ii.) than with the *T. capillata* of the Red Chalk figured by Davidson.

In this connexion we would recall the fact that *T. capillata* has been found by one of us in the Totternhoe Stone or 'Grey Bed' of Lincolnshire, and consequently well up in the Lower Chalk (see Quart. Journ. Geol. Soc. vol. xlv. p. 349). It has therefore a wider distribution in beds of Cenomanian age than in those of earlier epochs, and we are inclined to think that the Lower Greensand form figured by Davidson may have to be separated from it.

### Lamellibranchiata.

*OSTREA CANALICULATA*, SOW. = *O. LATERALIS*, Nilss.

This is the *Chama canaliculata* of the 'Min. Conch.' vol. i. pl. 26. fig. 1 (1812), not the *Ostrea canaliculata* of a later volume (pl. 135. fig. 1).

The *Chama canaliculata* of Sowerby is the *Ostrea lateralis* of Nilsson (1827), as pointed out by d'Orbigny; and, having compared many French and English specimens, we agree in regarding them as the same shell, but Sowerby's name has the priority.

The shell which Sowerby called *Ostrea canaliculata* cannot bear that name, and, as it seems to be identical with the *O. lunata* of Nilsson, it should be so designated.

*O. canaliculata* (Sow., sp.) is a characteristic Cenomanian shell, and *O. lunata* belongs to the highest White Chalk of Trimmingham and Mundesley.

### PECTEN INTERSTRIATUS, Leym.

This name has frequently appeared in lists of Cretaceous fossils, and has been applied indiscriminately to Lower and Upper Cretaceous species. Leymerie, in 1842, gave the name to an Aptien species which is figured by d'Orbigny under that name in the 'Pal. Fr. Terr. Crét.' pl. 433. figs. 1-5, but in his 'Prodrome' (vol. ii. p. 169) he changed the name to *aptiensis*, because he found that *interstriatus* had been used for another species by Münster in 1841. The latter name, therefore, should not be used for any of the Cretaceous *Pectens*. The Lower Greensand species (*P. aptiensis*) has its own distinctive characters and does not range into Gault or Upper Greensand though it doubtless was the ancestor of the later interstriate *Pectens*.

## PECTEN DUTEMPLEI, d'Orb., and PECTEN GALLIENNEI, d'Orb.

These are two of the species which have gone by the name of *interstriatus* in England. *P. Dutemplei* is described by d'Orbigny as having plain narrow ribs between the larger ornamented ribs, and as having its ears marked only by vertical lines of growth. *P. Gallienniei* he describes as wanting the intermediate ribs and as having several strong radiating ribs on the buccal ear. The first is supposed to be confined to the Gault (Albien) and the second to the Cenomanian. We do not feel certain that the latter is more than a variety of the former, or that they are confined to separate stages. M. Bizet has sent us a specimen from the Cénomanién of Condrecieux which he calls *P. Gallienniei*, though it has the intermediate ribs of *Dutemplei*. Specimens from La Hève, Warminster, and the Cenomanian of Devon do, however, agree better with *Gallienniei*, and we have therefore so named them.

PECTEN PASSYI, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. p. 309, pl. xv. fig. 9.

This is a fossil from the Tourtia of Tournay, and has a considerable resemblance to *P. Gallienniei*, d'Orb., but is described as having perfectly straight, regular, and plain ribs, without any scales or nodulations. The interspaces are striated in the usual manner. Mr. C. J. A. Meyer has specimens which possess these characters from his Bed 11, Dunscombe Cliff.

PECTEN SUBINTERSTRIATUS, d'Arch., Mém. Soc. géol. Fr. ser. 2, vol. ii. pl. xv. fig. 10.

Specimens which agree with the figure and description of d'Archiac occur in the Cenomanian of Devon. It is distinguished from the other interstriae species by its more numerous ribs, which are in low relief and are crossed by fine concentric lines of growth, each line where it crosses a rib developing a small short scale. These scales are much more numerous and much less prominent than those of *P. Gallienniei*; they are most strongly marked on the anterior portion of the shell, and are mere slight ridges on the central ribs. The ears are plain or marked only by vertical lines of growth; the anterior ear is much larger than the posterior.

D'Archiac figures only a right valve, and, as Leymerie only figured a left valve of his *P. interstriatus*, d'Archiac cautiously remarks that his specimen may be only a right valve of that species. We have, however, a left valve which is clearly that of *subinterstriatus*, the only difference being that the ribs are rather fewer and placed at less regular intervals.

The *P. subinterstriatus* figured in Dixon's 'Geology of Sussex,' pl. xxviii. fig. 19, is wrongly so named, but is doubtless the *P. cretosus* of DeFrance (non Goldf.), as stated on p. 386 of that work, this *P. cretosus* being probably the same as *P. nitidus*, Mantell.

*PECTEN ELONGATUS*, Lam.

There is much doubt about this species, because the figures given by d'Orbigny and Goldfuss are not alike, and because d'Orbigny's description does not agree with his figure. We take d'Orbigny's description as the best guide ('Pal. Fr.' p. 607), and from this we learn that it has 30 to 40 unequal ribs, sometimes alternating large and small ribs, sometimes grouped in threes (one large and two small ones), each having prominent lamellose scales at intervals. His figure, however, does not express these characters at all clearly. We have found specimens at La Hève which agree with his description exactly and are also identical with specimens from the Lower Chalk of England which we have been accustomed to regard as *P. elongatus*. In all of them there is a marked tendency for the ribs to be arranged in threes, a large one in the centre with a small one on each side.

Dr. Barrois states<sup>1</sup> that this species is identical with the form figured under the name of *P. cretosus* by Goldfuss ('Petr. Germ.' pl. xciv. fig. 2), and the figure certainly agrees with d'Orbigny's description. *P. elongatus* of Goldfuss is a Tertiary species.

It differs from *P. Marrotianus* in not having two minor ribs between each of the groups of three, in being much less regular, and in having much more prominent scales. We have not seen this species from the Cenomanian of Devon, though it ought to occur there.

*PECTEN* cf. *PUZOSIANUS*, Math. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 610, pl. 437. figs. 1-4.

This is another case in which d'Orbigny's figure and description do not entirely agree. The figure shows perfectly plain ribs of unequal breadth, but set close together, interrupted only by concentric lines of growth; yet d'Orbigny says that the ribs are furnished on the sides with imbricated plates: he adds, however, that these plates are wanting in the middle of the shell, 'but may there have been abraded.'

We have specimens both from France and from Devon which much resemble the figure, except that their ribs are rather fewer, flatter, and more strongly marked, but there is no trace of their ever having borne imbricating plates; possibly these were very delicate and easily removed. From its occurrence in the typical Cenomanian country we think that this must be the shell described by d'Orbigny.

*PECTEN SUBACUTUS*, Lam. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 605, pl. 435. figs. 5-10.

We had found a *Pecten* in the lowest part of the Devon Cenomanian which seemed to be this species, but its state of preservation

<sup>1</sup> 'Mém. sur le Terr. Crét. des Ardennes,' Ann. Soc. géol. du Nord, vol. v. (1878) p. 318.

was not good enough for certain identification. Fortunately, however, M. Bizet was so kind as to send us two specimens of *P. subacutus* from the Sarthe, and these enabled us to satisfy ourselves that the Devon species is the same. By the same means also Mr. Meyer has been able to identify a specimen in his collection. We have not seen it from any other locality, and it is another of the links which connect the Devon beds with the Cenomanian of the Sarthe.

#### PECTEN, sp.

A species occurs in the Cenomanian of France, and also in the highest greensand of Warminster, which we have not been able to identify. It bears a certain resemblance to *P. Raulinianus* of the Gault, and appears under that name in some lists, but the ornamentation is really very different. The shell bears a large number of narrow ribs, nearly straight, but of unequal size, smaller ribs being frequently, but not constantly, developed between those of normal size. Each rib bears a number of strong, triangular, spinous processes, arranged longitudinally, and projecting almost vertically upwards. Some of the smaller ribs bear similar but more slender spines, and some are nearly smooth. There are no striæ on the interspaces. The ears are not preserved on the few specimens that we have examined. We are not sure that it occurs in Devon, though some badly-preserved specimens resemble it.

LIMA SIMPLEX, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 545, pl. 418. figs. 5-7.

In the lower and most fossiliferous part of the Devon zone of *Ammonites Mantelli* there are several large, smooth species of *Lima*, and having obtained a specimen of *Lima simplex* from the Cenomanian of Vimoutiers, we find that one of the Devon species bears a close resemblance to it. It is large, compressed, and smooth over the greater part of the shell, but has a few narrow grooves on the anterior and posterior sides of each valve, which produce a sort of false ribbing on these portions of the shell.

LIMA HOPERI, d'Orb. (*non* Sow.), and LIMA CALYPSO, d'Orb.

D'Orbigny's figure of *Lima Hoperi* has led to some confusion, for it is certainly not the *Lima Hoperi* of Sowerby and Mantell, which is common in the Upper Chalk (Sénonien) of England, especially in the Margate Chalk. Assuming d'Orbigny's figure to be that of an adult specimen, it is much smaller, more compressed, and ornamented all over by shallow pitted grooves; whereas the true *L. Hoperi* is a large shell, more inflated, and smooth, except over narrow spaces on the anterior and posterior sides of each valve, which have a few faint grooves.

In the Cenomanian of Devon there is a *Lima* which somewhat resembles the shell figured by d'Orbigny as *L. Hoperi*, but it is more inflated, and has a deeper and more irregular set of pitted grooves over the greater part of the shell. This may be the *Lima*

*Calypso* of d'Orbigny, described in his 'Prodrome,' vol. ii. p. 167, as very near ('voisine') to *L. Hoperi*, but with more numerous punctated grooves, and occurring in the Cenomanian of Rouen.

*CORBIS ROTUNDATA*, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 113, pl. 280.

This is another shell, occurring in the Devon zone of *Ammonites Mantelli*, which the acquisition of French specimens has enabled us to identify. We should mention, however, that Mr. Meyer has specimens which he had previously determined to be *C. rotundata*. It is common in the sandy facies of the Cénomanien at Vimoutiers, Gacé, and Mortagne, though the shell so often remains in the matrix that it is difficult to obtain more than casts of it; the same is the case in Devon, but a comparison of the casts leaves no doubt as to the identification.

*ARCA LIGERIENSIS*, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 227, pl. 317.

This is another common shell in the French Cenomanian which had been detected in the Devon beds by Mr. Meyer. Having obtained several casts of it from Vimoutiers and elsewhere, we are also able to state that it is common in the hard rocky basement-bed of the Lower Chalk at Chard (commonly called 'Chloritic Marl').

*TRIGONIA AFFINIS*, Sow.

This species was at first regarded by Lycett as only a variety of *Tr. excentrica*, Park. (see 'Brit. Foss. Trigonæ,' Pal. Soc. Monogr. p. 94), but in his Addenda (p. 187) he separates it again, and points out the characters by which it is distinguished. The only specimens which he refers to this species are one said to have come from Blackdown, now in the Jermyn Street Museum, one from Haldon (Mr. Vicary), and one in Mr. Meyer's collection, from near Axmouth, which Mr. Meyer informs me came from his Bed 12, the upper part of our zone of *Ammonites Mantelli*. It is therefore a rare shell.

*TRIGONIA DUNSCOMBENSIS*, Lycett, 'Brit. Foss. Trig.' Pal. Soc. Monogr. p. 188, pl. xl. figs. 5, 6.

This species was entered in Mr. Meyer's list of 1874 as 'sp. allied to *Tr. sinuata*, Park.,' and was described as a new species by Lycett in 1877. Mr. Meyer informs us that it occurs throughout the zone of *Ammonites Mantelli*, in his Beds 10, 11, and 12, at Dunscombe, Branscombe, Whitecliff, and Pinhay.

It is allied to *Tr. affinis* and *Tr. excentrica*, but though he distinguishes it from these, Lycett does not attempt to disentangle the foreign synonyms, neither does he record *Tr. dunscombensis* from any other localities. Under *Tr. excentrica* he gives the *Tr. sinuata*, Park., in d'Orbigny as a synonym, and notes that d'Orbigny records this *Tr. sinuata* from the lower beds of his Terrain Turonien (i. e. Cénomanien) at Le Mans, St. Calais, and Condrecieux in the Sarthe. We have not been able to obtain specimens of this *Tr. sinuata*, but

we think it is very likely to be *Tr. dunscombensis*, for we now know that the beds are of exactly the same age.

The true *Tr. sinuata* of Parkinson is only the young state of *Tr. excentrica*, Park., and Lycett states (p. 189) that there is no certain record of *Tr. excentrica* occurring in a higher position than the Blackdown Greensand. Mr. Mejer tells us that he has *Tr. excentrica* from his Bed 2 (the horizon of the Cowstones of Lyme Regis), but that it does not occur in the zone of *Ammonites Mantelli*.

TRIGONIA DEBILIS, Lycett, 'Brit. Foss. Trig.' p. 189, pl. xl. fig. 8.

This is another species akin to *Tr. affinis*, but is at present only known from Bed 10 of Mr. Mejer's notation at Dunscombe. Lycett thinks that it is the young of a much larger species, but states that it is quite distinct from the young of any of the known 'Greensand' species of *Trigonie glabræ*.

TRIGONIA CRENULATA, Lam. in d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 151, pl. 295.

Mr. Mejer has a specimen of this species from Bed 12, obtained from a block on the shore of Pinhay Bay, near Lyme Regis. It is said to be a common fossil in the Cenomanian of Vimoutiers and Gacé, as well as near Le Mans, but we only succeeded in getting casts of *Trigonie* which might belong to it, or to the next.

TRIGONIA CRENULIFERA, Lycett, 'Brit. Foss. Trig.' p. 189, pl. xl. figs. 1, 7, 9.

This was separated from *Tr. crenulata* by Lycett, the species being founded on specimens in Mr. Mejer's collection. They came from Beds 10 and 11. 'The chief distinction consists in the prominent zigzag costellæ upon the area and escutcheon,' and the median furrow of the area is a 'deeply impressed groove' (*op. cit.*).

TRIGONIA MEYERI, Lycett, 'Brit. Foss. Trig.' p. 125, pl. xxiii. fig. 6.

A shell belonging to the *aliformis* group; it was referred to *Tr. abrupta*, Von Buch, by Mr. Mejer in 1874, but Lycett gave good reasons for regarding it as a new species, and named it after its discoverer. It occurs in Beds 11 and 12 at Dunscombe and Pinhay, and has also been found in the fossiliferous basement-bed of the Chalk at Chardstock.

TRIGONIA VICARYANA, Lycett, 'Brit. Foss. Trig.' pp. 141 & 203, with figs. on pls. xxiii., xxv., xxviii., & xl.

Lycett fully discussed this species, which he distinguished from *Tr. Archiaciana*, d'Orb. (an Aptien species). He subsequently adopted Mr. Mejer's opinion that *Tr. Archiaciana* does not occur in the Upper Greensand or Chloritic Marl of England, the Haldon specimens referred to that species belonging in reality to *Tr. Viaryana*.

Both Mejer and Lycett are inclined to regard the *Tr. spinosa* of

d'Orbigny, a common Cenomanian shell, as a synonym of this species. It is certainly not the true *Tr. spinosa* of Parkinson, and, having compared a specimen from the Chloritic Marl of Havre with d'Orbigny's figure of *Tr. spinosa* and with examples of *Tr. Vicaryana* from Devon, we believe them to be identical. *Tr. Vicaryana* is therefore a common shell on both sides of the Channel.

### Cephalopoda.

**AMMONITES COMPLANATUS**, Mant. See Sharpe, 'Chalk Mollusca' Pal. Soc. Monogr. p. 19, pl. vii. figs. 1-3. = *A. Largilliertianus*, d'Orb., 'Pal. Fr. Terr. Crét.' pl. xcv.

Having found a specimen of this rare shell in a fallen mass of Bed 11 on Pinhay beach, west of Lyme Regis, it is interesting to observe that Sharpe identifies it with *A. Largilliertianus*, which has been found in the Cenomanian of Rouen, and also in that of the Sarthe, according to M. Guillier ('Géologie de la Sarthe,' 1886). M. Guillier apparently considers the two forms to be distinct species, for he enters both of them in his list. The original English specimen was found in the Chalk Marl of Hamsey, near Lewes.

**AMMONITES EUOMPHALUS**, Sharpe, 'Chalk Mollusca,' p. 31, pl. xiii. fig. 4.

This is another very rare ammonite, of which only one specimen was known to Mr. Sharpe, obtained from the base of the Chalk in Man of War Cove, Dorset. Our specimen was found in the sandy chalk, Bed 13 of Mr. Meÿer, in the cliff below Whitlands coast guard station, west of Lyme Regis.

**AMMONITES GOUPILIANUS**, d'Orb., 'Pal. Fr. Terr. Crét.' vol. iii. p. 317, pl. xciv. figs. 1-3; and Sharpe, 'Chalk Mollusca,' p. 38, pl. xvii. figs. 5 & 6.

This is a sharply-keeled ammonite, with faintly-marked sigmoid ribs, resembling *A. varians* in form, but distinguished by its suture. Mr. Meÿer has found one specimen in Bed 13 below Whitlands. Mr. Sharpe had only seen one obtained from the 'Grey Chalk' of Hamsey (? Chalk Marl). It has not been found in the Cénomannien of Western France, but occurs in beds of Turonian age at Saumur on the Loire.

**AMMONITES LATICLAVIUS**, Sharpe, 'Chalk Moll.' p. 31, pl. xiv. fig. 1.

This form was only known to Sharpe from the Chloritic Marl of the Isle of Wight, but it has since been found in the upper part of the Lower Chalk of Yorkshire (see Quart. Journ. Geol. Soc. vol. xlv. 1888, p. 351). Dr. Barrois has found it to be not uncommon in the zone which he calls by its name in the North-east of France, and which appears to be equivalent to our Chloritic Marl. In Devon, Mr. Meÿer has found a specimen in Bed 11.

*AMMONITES OBTECTUS*, Sharpe, 'Chalk Moll.' p. 20, pl. vii. fig. 4.

This is another peculiar ammonite described by Sharpe from a single specimen obtained by Mr. Wiest at Chardstock, and is one of the many species which occur at that locality and on the coast. The specimen found by Mr. Meÿer came from his Bed 11, Dunscombe, and this and one<sup>1</sup> from the 'Chalk with many *Micrasters*' of Dover are, so far as we know, the only others yet discovered.

*AMMONITES RENEVIERI*, Sharpe, 'Chalk Moll.' p. 44, pl. xx. fig. 2.

This is a rare Lower Chalk fossil found in the Isle of Wight and near Devizes, and also obtained by Guéranger in the Cenomanian of Le Mans, so that it is one of the species which links the Devon beds with the Lower Chalk, on the one hand, and with the typical French Cenomanian on the other. Mr. Meÿer found it in Bed 13 on a large fallen block below Whitlands, near Lyme Regis.

*TURRILITES BECHII*, Sharpe, 'Chalk Moll.' p. 66, pl. xxvi. fig. 13.

The original specimen of this was found near Lyme Regis by Sir H. De la Beche. Mr. Meÿer has obtained specimens from his Beds 12 and 13 (see list). At present it is known only from Devon.

*AMMONITES (ACANTHOCERAS) PENTAGONUS*, sp. nov. (Pl. V. figs. 1 & 1 a.)

This shell has some resemblance in general shape and curvature to the flattened forms of *Ammonites Mantelli*, but in the number and arrangement of its dorsal tubercles it resembles *A. Deverianus*, d'Orb.

Only one specimen has been found, and this is figured in Pl. V. figs. 1 & 1 a. Its dimensions are:—longest diameter 4 inches, shortest 3 inches; height of last whorl 1·8 inch, and width of mouth about 1·6 inch.

The whorls are about three parts involute, and the umbilicus is consequently small. The sides are flattened and the back rounded. A certain number of ribs, probably about 18, start from a set of tubercles, which surround the umbilicus, but on the sides other ribs come in, one or sometimes two between each of the first set, all becoming of nearly equal size and passing regularly over the back.

Each rib bears five equidistant tubercles, three on the back and one on each side of these, where the back curves to meet the sides. Thus, viewed from the back, five rows of tubercles are visible, the median row being the most prominent, and the two outer rows being the least elevated.

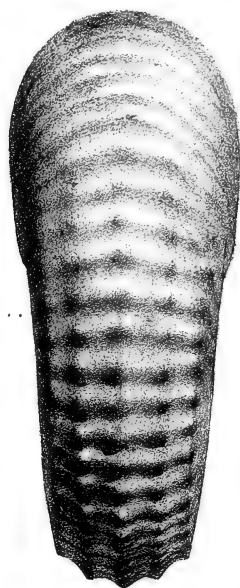
The ribs and tubercles are best developed in the younger part of the shell. In the body-chamber beyond the last sutural line some curious changes take place; for a space on the sides the ribs almost disappear, then the tubercles on the back become smaller, and near

<sup>1</sup> W. Hill on the Chalk of Dover, Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 242.

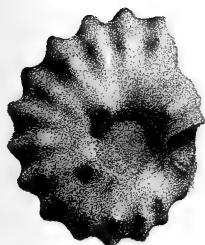




1.



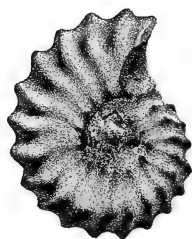
1a.



2.



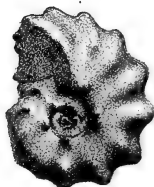
3a.



4.



2a.



3.



4a.



the mouth there is a set of strong, plain, rounded ribs without any tubercles, which pass over the back and along the sides till they nearly meet the ribs which start from the umbilical tubercles.

It is most nearly allied to *A. Deverianus*, but this species, as figured by d'Orbigny and Sharpe, differs in the following particulars: it is much less involute and more inflated than *A. pentagonus*, it has a much wider umbilicus, there is an extra row of tubercles along the middle of each side of the shell, and the median dorsal row is less prominent. Finally the ribs on the sides of the body-chamber break up into a number of large nodular tubercles.

The fossil now described is a phosphatic cast, and was found by one of us (A. J. J.-B.) in the glauconitic chalk (? Bed 13) above the zone of *Ammonites Mantelli*, in a fallen block at Humble Point, east of Charton Bay, near Lyme Regis. The name *pentagonus* refers to the pentagonal outline of the dorsal surface. It is doubtless a derived fossil and is associated with *A. hippocastanum*, *A. navicularis*, and *Scaphites æqualis*.

AMMONITES (ACANTHOCERAS) HIPPOCASTANUM, Sharpe, var. COMPRESSUS, NOV. (Pl. V. figs. 2-4 a.)

The specimens to which we here draw attention may be regarded as a variety of the above species, but so different are they in general appearance that we were at first inclined to regard them as a distinct species. They do not, however, differ from *A. hippocastanum* more than some varieties of *A. varians* do from *A. Coupei*, and in both cases intermediate forms occur. Messrs. Sharman and Newton have kindly examined the specimens and concur in this view. But a form which departs so greatly from the figured type seems to merit description and illustration, especially as it is by no means uncommon on the Devon coast, in the layer of phosphatic nodules which are often cemented to the top of the *A. Mantelli*-zone (Bed 12), and in the overlying glauconitic chalk (Bed 13). It may be mentioned that the ordinary inflated form of *A. hippocastanum* is present in the same beds.

For the compressed form now described the varietal name of *compressus* is proposed. The dimensions of that figured in Pl. V. figs. 4 & 4 a are:—longest diameter 1.2 inch, lesser diameter about .88 (seven-eighths) of an inch, width of the mouth about .3 of an inch. The whorls are broad, the sides flattened, and the back elevated. About twenty tuberculated ribs pass over the back, but nearly half of these die away on the sides, converging to a row of ten or eleven tubercles which surround the umbilicus.

Viewed from the back, five rows of tubercles are visible, but the two outer rows are small and distant. The three inner rows are set close together along the back and are laterally compressed, so that the back is narrow and has a very different aspect from that of the typical *hippocastanum*, which further differs in having large and prominent lateral tubercles. Nevertheless varieties occur which seem to link this form with *hippocastanum*, and one of them is

figured in Pl. V. figs. 3 & 3*a*. This has only about thirteen ribs to the whorl, and only five umbilical tubercles; the whorls are narrow and less involute, all characters which bring it closer to the typical form, but the narrow back and flattened sides keep it under the variety *compressus*.

A third variety comes still closer to the *hippocastanum* of Sharpe, being more inflated and having more prominent lateral tubercles; the back, however, resembles the variety *compressus* in the close-set rows of elongate and laterally-compressed tubercles, so that its characters are distinctly intermediate between the two extreme forms. This is figured in Pl. V. figs. 2 & 2*a*.

## VII. LISTS OF CENOMANIAN FOSSILS FOUND IN DEVON AND IN NORMANDY.

### 1. Fossils from the Cenomanian of Devon.

The following list represents the fauna of the beds that we have described in Devon, so far as it has been worked out. We have grouped them in three columns only, for the reasons stated on p. 142. The bed A of this list includes fossils obtained by Mr. Meyer in his Beds 10 and 11 from all localities except Beer Head, where we regard his 11 as part of 12. Bed B is the same as his Bed 12 plus the 11 of Beer Head only, Mr. Meyer having informed us which of his fossils came from the 11 of that locality. Bed C is Mr. Meyer's 13.

The fourth column shows how many of the fossils found in the Cenomanian group of the coast occur also at the base of the Chalk near Chard and Chardstock. This column is a nearly complete list of the Chard fauna, for there are very few of the fossils found there which do not also occur on the coast.

The last column indicates the species occurring in beds A, B, and C which are also found in the true Cenomanian of the North-west of France—*i. e.*, of the departments of the Seine Inferieure, Calvados, Orne, and Sarthe.

The letters by which the fossils are indicated in the first three columns have the following signification:—

S means: collected by ourselves or by Mr. Rhodes for the Geological Survey.

H means: identified by Dr. Hinde from specimens sent to him by ourselves.

M means: identified by Mr. Meyer from specimens in his own collection.

	DEVON.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
SPONGES.					
<i>Elastostoma consobrinum</i> .....	H	...	...	...	*
"    sp. ....	H	...	...	...	*
<i>Trematocystia d'Orbigny</i> , Hinde .....	H	...	...	...	*
" <i>siphonoides</i> , Mich. ....	H	...	...	...	*
<i>Nematinion calyculatum</i> .....	H	...	...	...	*
"    sp. ....	H	...	...	...	*
HYDROZOA.					
<i>Porosphaera</i> , sp. ....	H	...	...	...	* ?
? Genus (concentric layers) .....	H	...	...	...	*
? Genus (tubular) .....	H	...	...	...	*
ACTINOZOA.					
<i>Microbacica coronula</i> , Goldf. ....	S M	...	S M	...	*
<i>Thamnastræa</i> , sp. ....	H	...	...	...	*
ECHINODERMATA.					
<i>Caratodus rostratus</i> , Ag. ....	S M	S M	S M	...	*
<i>Catopygus columbarius</i> , Lam. ....	S	M	...	*	*
<i>Cidaris vesiculosa</i> , Goldf. (test) .....	S	M	...	...	*
"    sp. (spines) .....	S	...	...	...	*
<i>Codiopsis doma</i> , Desm. ....	...	M	...	...	*
<i>Cottalidia Benettii</i> , Koenig .....	S M	M	...	...	*
<i>Discoidea cylindrica</i> , Lam. ....	...	S ?	S M	*	*
" <i>Favrina</i> .....	S	S M	S	*	*
" <i>subucula</i> , Klein .....	S M	S M	S M	*	*
<i>Echinobrissus lacunosus</i> , Goldf. ....	...	M	...	...	*
<i>Echinoconus castaneus</i> , Brongn. ....	S	M	S M	*	*
<i>Echinocyphus difficilis</i> , Ag. ....	...	...	M	*	*
<i>Glyphocyphus radiatus</i> , Høninghaus .....	...	...	M	*	*
<i>Goniophorus lunulatus</i> , Ag. ....	M	...	...	...	*
<i>Hemiasper Morrisii</i> , Forbes .....	...	M	...	...	*
<i>Holaster</i> , sp. ....	S M	S	...	...	*
<i>Holaster lævis</i> , Deluc .....	S M	M	S	*	*
"    "    var. <i>carinatus</i> , Ag. ....	S M	...	...	?	*
" <i>suborbicularis</i> , Brongn. ....	M	...	...	...	*
" <i>suborbicularis</i> , Wright .....	M	...	...	...	*
" <i>subglobosus</i> , Leske .....	S M	S M	? M	*	*
<i>Holactypus bistriatus</i> , Wright .....	...	M	...	...	*
<i>Pseudodiadema Benettii</i> , Forbes .....	M	...	...	...	*
" <i>Brongniarti</i> (?), Ag. ....	...	...	M	*	*
" <i>Michelini</i> , Ag. ....	...	M	M	...	*
" <i>ornatum</i> , Goldf. ....	S	...	M	*	*
" <i>variolare</i> , Brongn. ....	S M	...	S M	*	*
<i>Pygurus lampas</i> , De la Beche .....	M	...	...	...	*
<i>Pyrina lævis</i> , Ag. ....	S	...	M	...	*
" <i>Desmoulinii</i> , D'Arch. ....	...	M	...	...	*

TABLE (continued).

	DEVON.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
ECHINODERMATA (cont.).					
<i>Pyrina ovulum</i> (?), Ag. ....	M	M	...	*	
<i>Salenia petalifera</i> , Desm. ....	S M	M	...	*	*
"    "    var. <i>gibba</i> , Ag. ....	...	M	...	...	*
" <i>Clarkii</i> (?), Forbes ....	S	...	S		
<i>Trematopygus</i> ?, sp. nov. ....	...	M			
ANNELIDA.					
<i>Ditrupa difformis</i> , Lam. ....	...	S	M	*	*
<i>Galeolaria plexus</i> , Sow. ....	S	...	...	*	*
<i>Vermicularia umbonata</i> , Mant. ....	S				
CRUSTACEA.					
<i>Callianassa</i> , sp. ....	M	M			
POLYZOA.					
<i>Eschara neustriaca</i> , Mich. ....	H	...	...	...	*
"    sp. ....	H				
<i>Ceripora</i> (sp. 12) ....	H	H			
"    (sp. 25) ....	H				
<i>Reptomulticlausa papularis</i> , Mich. ....	H	...	...	...	*
<i>Ceriacava ramulosa</i> , Mich. ....	H	...	...	...	*
<i>Defrancia</i> ( <i>Pelagia</i> ) <i>Eudesii</i> , Mich. ....	H	...	...	...	*
<i>Micropora</i> (sp. 4) ....	H	...	...	...	*
"    (sp. 5) ....	H	...	...	...	*
<i>Radiopora</i> ( <i>Cellulipora</i> ) <i>ornata</i> , d'Orb. ....	H	...	...	...	*
BRACHIOPODA.					
<i>Crania cenomanensis</i> (?), d'Orb. ....	...	M	...	*	*
<i>Magas Geinitzi</i> (?), Schloenb. ....	M				
<i>Megerlia</i> ( <i>Kingena</i> ) <i>lima</i> , DeFr. ....	S	S M	M	...	*
<i>Rhynchonella convexa</i> , Sow. ....	S M	S M	M	*	*
" <i>dimidiata</i> , Sow. ....	S M	S M	S M	*	*
"    "    var. <i>gallina</i> , Brong. ....	S M	S	...	...	*
" <i>Grasiana</i> , d'Orb. ....	S M	S M	M	...	*
" <i>Cuvieri</i> , d'Orb. ....	...	...	S	...	
" <i>Mantelliana</i> (?), Sow. ....	...	S	S	...	
" <i>Schloenbachi</i> , Dav. ....	S M	M	...	...	*
" <i>sigma</i> , Schloenb. ....	...	M			
" <i>Wiestii</i> , Quenst. ....	...	S M	S M	*	
<i>Terebratula arenosa</i> , d'Arch. ....	...	M			
" <i>arcuata</i> , Roem. ....	...	S M	...	*	*
" <i>capillata</i> , d'Arch. ....	...	M	...	...	*
" <i>obesa</i> (?), Sow. ....	...	M	...	...	*
" <i>ovata</i> , Sow. ....	S	M	M	...	*
" <i>semiglobosa</i> , Sow. ....	S	...	...	*	*
" <i>squamosa</i> , Mant. ....	S	M	...	*	*

TABLE (continued).

	DEVON.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
BRACHIOPODA (cont.).					
<i>Terebratula tornacensis</i> , d'Arch. ....	...	M	...	...	*
<i>Verneuilii</i> , d'Arch. ....	M	M	...	...	*
<i>Terebratella pectita</i> , Sow. ....	S	M	...	...	*
<i>Menardi</i> , d'Orb. ....	S	M	...	*	*
<i>Thecidium</i> , sp. ....	M	M	...	...	...
<i>Trigonosemus incertus</i> , Dav. ....	...	M	S M	*	...
<i>Terebrirostra lyra</i> , Sow. ....	S	...	...	...	*
LAMELLIBRANCHIATA.					
<i>Anomia</i> , sp. ....	S	M	...	...	...
<i>Chama cornucopiæ</i> (?), d'Orb. ....	S	...	...	*	...
<i>Exogyra conica</i> , Sow. ....	S	M	...	...	*
<i>Inoceramus latus</i> (?), d'Orb. ( <i>non</i> Mant.) ....	S M	...	...	*	*
<i>striatus</i> , Sow. ....	S M	...	...	*	*
sp. (elongated) ....	S	...	...	...	...
<i>Lima</i> (like <i>intermedia</i> , d'Orb.) ....	...	M	...	*	...
<i>globosa</i> , Sow. ....	S	...	...	*	...
<i>ornata</i> , d'Orb. ....	S M	M	M	*	*
<i>rapa</i> , d'Orb. ....	M	...	...	...	...
<i>rotomagensis</i> , d'Orb. ....	M	...	...	...	*
<i>semiornata</i> , d'Orb. ....	S M	M	...	...	*
<i>semisulcata</i> , d'Orb. ....	M	...	...	*	*
<i>simplex</i> , d'Orb. ....	S M	...	...	...	*
<i>tecta</i> , d'Orb. ....	M	...	...	...	*
sp. (with pitted grooves) ....	S	S	...	...	?
<i>Lithodomus rugosus</i> , d'Orb. ....	S M	...	...	*	...
<i>Modiola</i> ( <i>Mytilus</i> ) <i>divaricata</i> , d'Orb. ....	M	...	...	...	*
<i>capitata</i> ?, Zittel ....	...	M	...	...	...
<i>Guerangeri</i> , d'Orb. ....	...	M	...	...	*
<i>lineata</i> , Sow. ....	S	S M	S	*	*
<i>ligeriensis</i> , d'Orb. ....	...	M	...	...	...
<i>striatocostata</i> , d'Orb. ....	M	...	...	...	*
(? genus) <i>arcacea</i> , Gein. ....	M	...	...	...	...
<i>irregularis</i> , Gein. ....	...	M	...	...	...
<i>Janira æquicostata</i> , Lam. ....	S	M	M	...	*
<i>quadricostata</i> , Lam. ....	...	...	...	...	*
<i>phaseola</i> , Lam. ....	...	M	M	...	*
<i>quincocostata</i> , Sow. ....	S M	M	M	*	*
<i>decemcostata</i> , Münst. ....	M	...	...	...	...
sp. ....	M	...	...	...	...
<i>Ostrea carinata</i> , Sow. ( <i>frons</i> , Park.) ....	S M	M	...	*	*
<i>hippopodium</i> , Nilss. ....	S M	M	...	...	*
<i>diluviana</i> , Linn. ....	S M	...	...	...	*
<i>vesicularis</i> , Lam. ....	S	...	...	*	*
<i>Pecten asper</i> , Lam. ....	S M	?	...	*	*
<i>acuminatus</i> , Gein. ....	M	M	...	...	...
<i>elongatus</i> (?), Lam. (or new sp.) ....	S	...	...	...	*
<i>Galliennii</i> , d'Orb. ....	S	...	...	...	*
<i>orbicularis</i> , Sow. ....	S	...	...	...	*

## TABLE (continued).

	DEVON.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
LAMELLIBRANCHIATA (cont.).					
<i>Pecten Puzosianus</i> , d'Orb. ....	S	M	...	...	*
„ <i>Passyi</i> , d'Arch. ....	M	...	...	...	...
„ <i>rotomagensis</i> , d'Orb. ....	M	...	...	...	*
„ <i>subacutus</i> ....	S M	...	...	...	*
„ <i>subinterstriatus</i> , d'Arch. ....	S M	M	...	...	*
<i>Plicatula inflata</i> , Sow. ....	...	...	S M	*	*
<i>Spondylus Dutempleanus</i> , d'Orb. ....	S	...	...	...	*
„ <i>Omalii</i> , d'Arch. ....	...	M	...	...	*
„ <i>striatus</i> , Sow. ....	S	...	...	...	*
<i>Anatina lanceolata</i> , Gein. ....	M	S	...	...	*
<i>Arca Mailleana</i> , d'Orb. ....	...	M	M	...	*
„ <i>Galliennii</i> , d'Orb. ....	...	M	...	...	*
„ <i>ligeriensis</i> , d'Orb. ....	S M	...	...	*	*
„ sp. ....	S	...	...	...	...
<i>Astarte cyprinoides</i> , d'Arch. ....	M	...	...	...	...
„ <i>Koninckii</i> , d'Arch. ....	M	...	...	...	...
<i>Cardita</i> , sp. (cast) ....	...	...	S	*	...
<i>Cardium alternans</i> , Reuss ....	M	...	...	...	...
„ <i>alutaceum</i> , Goldf. ....	M	...	...	...	...
„ <i>Mailleanum</i> , d'Orb. ....	...	M	...	...	*
„ <i>Hillanum</i> , Sow. ....	S	M	...	...	*
<i>Corbis rotundata</i> , d'Orb. ....	S M	...	...	*	*
<i>Crassatella vindennensis</i> , d'Orb. ....	...	M	...	...	*
„ <i>ligeriensis</i> , d'Orb. ....	...	M	...	...	*
<i>Cucullæa</i> , sp. ....	S	...	...	...	...
<i>Gastrochæna</i> , sp. ....	S M	...	...	...	...
<i>Lucina turoniensis</i> (?), d'Orb. ....	S	M	M	...	*
<i>Opis</i> , sp. ....	S M	...	...	*	?
<i>Pectunculus lens</i> , Nilss. ....	M	...	...	...	...
<i>Solen æqualis</i> , d'Orb. ....	M	...	...	...	*
<i>Trigonia affinis</i> , Sow. ....	S	M	...	*	*
„ <i>costigera</i> , Lyc. ....	M	...	...	...	...
„ <i>crenulata</i> , Lam. ....	...	M	...	...	*
„ <i>crenulifera</i> , Lyc. ....	S M	...	...	?	...
„ <i>debilis</i> , Lyc. ....	M	...	...	...	...
„ <i>dunscombensis</i> , Lyc. ( <i>sinuata</i> , d'Orb.) .	M	M	...	...	*
„ <i>Meyeri</i> , Lyc. ....	S M	M	...	*	...
„ <i>pennata</i> , Sow. ....	S M	...	...	...	...
„ <i>scabra</i> , Lam. ....	M	...	...	...	*
„ <i>sulcataria</i> , Lam. ....	M	M	...	...	*
„ <i>Vicaryana</i> , Lyc. ( <i>spinosa</i> , d'Orb.) ....	S M	S	...	*	*
<i>Pholadomya æquivalvis</i> , Goldf. ....	...	...	M	...	...
<i>Thetis Sowerbyi</i> (?), Rœm. ....	...	...	S	...	*
<i>Unicardium ringmeriense</i> , Mant. ....	...	M	M	*	...
<i>Venus Goldfussi</i> , Gein. ....	...	M	...	...	...
GASTEROPODA.					
<i>Aporrhais</i> ....	S	...	...	...	...
<i>Aveilana cassisi</i> , d'Orb. ....	...	S M	S	*	*



TABLE (continued).

				DEVON.	Chard and Chardstock.	N.W. of France.
				Bed A.		
GASTEROPODA (cont.).						
<i>Avellana Prevosti</i> , d'Arch. ....	...	...	M			
<i>Columbellina</i> , sp. ....	S	M	...			?
<i>Emarginula Meyeri</i> , Gard. ....		M				
<i>Fusus</i> sp. ....	S M	S M				
<i>Natica gaultina</i> , d'Orb. ....	S		...			*
" sp. ....		M				
<i>Neritopsis</i> ....		M				
<i>Nerinea</i> ....	M		...			?
<i>Pleurotomaria Cassissiana</i> , d'Orb. ....		M	...			} several species.
" <i>Mailleana</i> , d'Orb. ....		M	...			
" cf. <i>gigantea</i> ....	S M		...			
" <i>Rhodani</i> , P. & Roux ....			S			
" sp. 1 ....		M				
" sp. 2 ....		M				
<i>Pterodonta</i> (several species) ....	M		...			* several species.
<i>Rostellaria Mailleana</i> , d'Orb. ....	M		...			*
<i>Solarium ornatum</i> , Sow. ....		M	...			*
" <i>Thirrianum</i> (?), d'Arch. ....	S		...			
<i>Trochus girondinus</i> , d'Orb. ....	...	M				
" sp. (like <i>cirrus</i> , Woodw.) ....		M				
" sp. ....	M		...			*
<i>Turbo Guerangeri</i> , d'Orb. ....		M	...			*
" (six other species) ....		M				
<i>Turboidea</i> , sp. ....	S	S				
<i>Turritella Bauga</i> , d'Orb. ....	M		...			*
" sp. ....	M		...			*
<i>Voluta Guerangeri</i> , d'Orb. ....	...	M	...			*
CEPHALOPODA.						
<i>Belemnitella lanceolata</i> , Sow. (non Schloth.) ...	S					
" <i>plena</i> , Blainv. ....			S M			*
<i>Nautilus Fittoni</i> , Sharpe ....	S	M	S			*
" <i>expansus</i> , Sow. ....	S					*
" <i>Deslongchampsianus</i> , d'Orb. ....			M			*
" <i>Fleurbaeyianus</i> , d'Orb. ....		M				*
" <i>Largillierianus</i> , d'Orb. ....		M				*
" <i>laevigatus</i> , d'Orb. ....		S M				*
" <i>subradiatus</i> (?), d'Orb. ....	S					*
<i>Ammonites Austeni</i> , Sharpe ....		S				*
" <i>complanatus</i> , Mant. ....	S					*
" <i>curvatus</i> , Mant. ....	S M	M				*
" <i>euomphalus</i> , Sharpe ....			S			
" <i>falcatus</i> , Mant. ....	S M	M				*
" <i>Goupilianus</i> , d'Orb. ....			M			
" <i>hippocastanum</i> ....			S M			*
" <i>laticlavus</i> , Sharpe ....	M					
" (?) <i>leptonema</i> , Sharpe ....			M			

TABLE (continued).

	DEVON.			Chard and Chardstock.	N.W. of France.
	Bed A.	Bed B.	Bed C.		
CEPHALOPODA (cont.).					
<i>Ammonites Mantelli</i> , Sow. ....	S M	M	...	*	*
<i>navicularis</i> , Sow. ....	S M	M	S M	*	*
<i>pentagonus</i> , sp. nov. ....	...	...	S	...	...
<i>planulatus</i> , Sow. ....	S	...	M	*	...
<i>obtectus</i> , Sharpe.....	M	...	...	*	...
<i>Renevieri</i> , Sharpe .....	...	...	M	...	*
<i>rotomagensis</i> , DeFr. ....	...	M	S M	*	*
<i>varians</i> , Sow. ....	S	M	...	*	*
"    var. <i>Coupei</i> , Brong. ....	S M	M	...	*	*
<i>Wiestii</i> , Sharpe (? = <i>dispar</i> , d'Orb.).	S	...	...	*	?
<i>Scaphites æqualis</i> , Sow. ....	S	S M	S M	*	*
"    var. <i>obliquus</i> , Sow. ....	...	...	M	*	*
<i>Turrilites Bechei</i> , Sow. ....	...	M	M	...	...
<i>costatus</i> , Lam.....	S	M	...	*	*
<i>Gravesianus</i> , d'Orb. ....	...	M	...	...	...
<i>Morrisii</i> , Sharpe .....	...	M	...	*	...
<i>Scheuchzerianus</i> , Bosc .....	S	...	...	...	*
<i>tuberculatus</i> , Bosc .....	S	...	M	*	*
<i>Hamites simplex</i> (?), d'Orb. ....	S	...	M	...	*
PISCES.					
<i>Lamna appendiculata</i> (?), Ag. ....	S	...	S	...	...
<i>Ptychodus decurrens</i> , Ag. ....	...	M	...	...	...
<i>Scapanorhynchus</i> .....	S	...	...	...	...
<i>Oxyrhina Mantelli</i> , Ag. ....	S	...	...	...	...

From the above list it will be seen that the fauna of the Devon zone of *Ammonites Mantelli* is the fauna of the Cenomanian of the North-west of France. There are 10 species which are at present only known from their occurrence in these beds or near Chard. Deducting these from a total of 195 species and varieties of invertebrata, we have 185 which occur elsewhere, and out of these 132 are found to occur in the Cenomanian of Western France; while some others, such as *Echinocyphus difficilis*, *Magas Geinitzi*, *Ammonites planulatus*, *A. laticlavus*, *A. leptonema*, and *A. euomphalus*, etc., occur in beds of Cenomanian age elsewhere.

Moreover there are 4 echinoderms, 18 lamellibranchs, and 6 or more gasteropods which are not known to occur elsewhere in England, but which are common to this Devon deposit and the Cenomanian of Western France. Mr. Meyer's collection includes many species of gasteropoda which he has not been able to name, but we think it very probable that, if they could be compared with

specimens from the sands of the Sarthe, many of them would be found to agree with known Cenomanian species.

The Devon fauna has also a strong affinity with that of the Tourtia of Tournay, in Belgium. Several Tourtia species occur which have not yet been recorded from the Cenomanian of Western France. These are *Terebratula arenosa*, *T. Verneuilii*, *Pecten Passyi*, *P. subinterstriatus*, *Spondylus Omalii*, *Astarte cyprinoides*, *A. Koninckii*, *Avellana Prevosti*, and *Solarium Thirrianum* (?), nine species in all; besides two species which we have for the first time recognized in the Western Cenomanian, namely, *Terebratula capitata* and *T. tornacensis*.

In order to compare this Devon Cenomanian fauna with that of the Warminster Greensand it will be necessary to examine the chief collections of Warminster fossils, not only for the purpose of submitting many of the species to a critical examination, but in order to weed out of them all the specimens which are preserved in phosphate of lime, for these have really been obtained from the overlying Chloritic Marl and not from the green sand which lies between it and the Chert Beds. This investigation is not yet completed, but we are able to state that the Warminster Greensand contains comparatively few gasteropoda or cephalopoda, that *Ammonites Mantelli* and *A. navicularis* are rare shells in it, and that *Turritiles costatus* and *T. tuberculatus* do not occur.

It is true that many echinodermata, brachiopoda, and lamelli-branchiata are common to the Devon and Warminster deposits, but these are shallow-water forms which would be likely to survive, and to be found in the shallow-water deposits of a slightly later date than that in which they first appear.

When the fauna found in Devon is compared with that of the Lower Chalk, say that of the Isle of Wight, we find a relationship of just the opposite kind. The *Nautili*, *Scaphites*, *Ammonites*, and *Turritiles* which are commonest in Devon are also those which abound in the Chloritic Marl and Chalk Marl of the Isle of Wight. Moreover, there are other species, such as *Ammonites Austeni*, *A. complanatus*, *A. euomphalus*, *A. Goupilianus*, *A. laticlavus*, *A. leptonema* (?), and *A. Renevieri*, which are much more rarely met with, but which have hitherto been found only in the Chalk Marl or in its basement-bed. When, however, we turn to the echinoderms, brachiopods, and lamellibranchs, we do not find so many of the Devon species in the Chalk Marl as in the Warminster Greensand; but, as no one doubts that the Chalk Marl was formed in a deeper sea than the Warminster Greensand, this absence of certain species is not to be wondered at.

We would remark that a mere percentage comparison of the faunas of two deposits is not of much value in determining their relative age, even when they occur within the same ancient province, unless there is good reason to suppose that they were formed in water of about the same depth. If, on the other hand, one is a deposit of shallower water than the other, the creatures which are most affected by the difference, such as sponges, polyzoa, brachiopoda, echino-

dermata, and all mollusca, except the cephalopoda, must be neglected in the comparison, and with reference to geological age only the cephalopoda should be admitted as evidence.

## 2. Fossils from the Cenomanian of Normandy.

The following list contains only the fossils obtained by ourselves at the places named, together with a few others for which we have the authority either of M. Lennier or M. Lecœur, and a few occurrences of particular echinodermata mentioned by Wright or in d'Orbigny's volumes.

A complete list of Cenomanian fossils, including those found in the Sarthe, would be a very long one, and would not serve any specially useful purpose. The present list may be taken to include all the commoner fossils of the more calcareous facies of the Cenomanian in North-western France, such species as would generally be met with by any collector. A full list of the fossils found in the Cenomanian of the Sarthe has been given by Guillier.<sup>1</sup>

For the identification of the sponges, polyzoa, and hydrozoa we are indebted to Dr. G. J. Hinde, F.G.S.; the other fossils have been determined by ourselves.

The first column contains all the fossils met with in the Cenomanian of the cliff-section near Havre, the second shows those found at and near Orbiquet, and the third those from Vimoutiers and Lisores. It should be mentioned that many in this third column are specimens given us by M. Lecœur. In these columns fossils examined and identified by ourselves are indicated by asterisks; those mentioned by others are indicated by letters—L standing for Lennier, Le for Lecœur, O for d'Orbigny, and W for Wright.

In order to compare this fauna with that of the Warminster Greensand on the one hand and the Lower Chalk on the other, we have indicated in the fourth and fifth columns the species which occur in these formations. By the Warminster Greensand we mean the sand lying between the Chert Beds of Warminster and the Chloritic Marl, and, so far as we can ascertain, 58 species out of 99 are common to the French Cenomanian and the Warminster Greensand, polyzoa being excluded.

The Lower Chalk of the fifth column is regarded as including the Chloritic Marl and the basement-beds of Dorset and Chard, but does not include the species which only occur in its representative on the Devon coast. Such species as only occur in the basement-beds are indicated by the letter B. Including these, 63 out of 99 species are common to the French Cenomanian and our Lower Chalk. Polyzoa are left out of account, because the Cretaceous species are greatly in need of revision, and it is uncertain what species range into the Lower Chalk.

It appears, therefore, that the percentage of Cenomanian species

<sup>1</sup> 'Géologie de la Sarthe,' Le Mans, 1886.

occurring in the Lower Chalk is a little larger than that occurring in the Warminster Greensand. We do not, however, rely greatly on this method of comparison; as already mentioned, it is to the cephalopoda alone that we look for reliable palæontological evidence regarding the age of such different deposits. Now the Cenomanian cephalopoda in our list number 14; of these only 7 occur at Warminster, while all of them occur in the Lower Chalk. Further, of those in the Warminster Greensand all except three (*Ammonites varians*, *A. Coupei*, and *A. falcatus*) are rare fossils, while in the Lower Chalk nearly all are very common. This evidence is very strongly in favour of the view for which we contend, and its force will be further alluded to in the sequel.

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
<b>PORIFERA (SPONGES).</b>					
<i>Corynella rugosa</i> , Hinde .....	*	...	...	*	
" , sp. ....	*	...	...	*	
<i>Elasmostoma consobrinum</i> , d'Orb. ....	*	...	...	*	
" <i>plicatum</i> , Hinde .....	*	...	...	*	
<i>Trematocystis siphonioides</i> , Mich. ....	*	...	...	*	
" <i>d'Orbigny</i> , Hinde .....	*	...	...	*	
<i>Jerea</i> , sp. ....	*	...	...	*	
<i>Pachypoterion compactum</i> , Hinde .....	*	...	...	*	
<i>Plocoscyphia</i> , sp. (fragments) .....	*	...	*	*	
<i>Stauronema Carteri</i> , Sollas .....	*	...	...	...	B
<b>HYDROZOA.</b>					
<i>Porosphaera urceolata</i> , Phil. ....	*	...	...	*	
" sp. ....	*	...	...	*	
<b>ACTINOZOA.</b>					
<i>Micrabacia coronula</i> , Goldf. ....	*	...	...	*	*
<b>ANNELIDA.</b>					
<i>Ditrupa difformis</i> , Lam. ....	*	...	...	*	*
<i>Galeolaria filiformis</i> , Sow. ....	...	*	...	*	*
" <i>plexus</i> , Sow. ....	*	...	...	*	*
<b>CRUSTACEA.</b>					
<i>Scalpellum</i> .....	*				

TABLE (continued).

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
<b>ECHINODERMATA.</b>					
<i>Caratopus rostratus</i> , Ag. ....	*	...	...	*	
<i>Catopygus columbarius</i> , Lam. ....	*	*	*	*	B
<i>Cidaris vesiculosa</i> , Goldf. ....	*	...	*	*	*
<i>Cottalidia Benettii</i> , König ....	*	...	*	*	
<i>Discoidea subucula</i> , Leske ....	*	*	*	*	*
<i>Epiaster crassissimus</i> , DeFr. ....	*	*	*	*	*
<i>Goniophorus lunulatus</i> , Ag. ....	W	...	W	*	
"    new sp. ....	*	...			
<i>Glyphocyphus radiatus</i> , Desor ....	*	...	Le		*
<i>Hemiaster bufo</i> , Desor ....	O	...	*		
<i>Holaster carinatus (lævis)</i> ....	*	*	...	*	*
"    subglobosus, Leske ....	*	...	...	*	*
<i>Peltastes acanthoides</i> , Ag. ....	O	...	O		
"    clathratus, Ag. ....	W	...	...	*	*
<i>Pseudodiadema ornatum</i> , Desor ....	*	...	*	*	*
" <i>Benettii</i> , Forbes. ....	*	...	...	*	B
" <i>Normanniæ</i> , Cott. ....	...	...	W		
" <i>Michelini</i> , Ag. ....	W	...	W	*	B
" <i>variolare</i> , Ag. ....	*	*	*	*	*
<i>Salenia Clarkii</i> (?), Wright ....	*	...	...	...	*
" <i>petalifera</i> , Ag. ....	*	...	...	*	B
" <i>scutigera</i> (?), Gray ....	*				
<b>POLYZOA.</b>					
<i>Alecto</i> , sp. ....	*				
<i>Ceriopora</i> i ( <i>Ceriocara</i> ) <i>mammillaris</i> , d'Orb. ....	*				
<i>Diastopora</i> , sp. a. ....	...	...	*		
"    sp. b. ....	*				
"    sp. c. ....	*				
<i>Entalophora ramosissima</i> , d'Orb. ....	...	...	*	*	
<i>Heteropora</i> , sp. ....	*				
<i>Sparsicava irregularis</i> , d'Orb. ....	*				
<i>Melicertites compressa</i> , d'Orb. ....	*				
<i>Idmonea ramosa</i> , Mich. ....	*				
<i>Radiopora ornata</i> , d'Orb. ....	*				
" <i>tuberculata</i> , d'Orb. ....	*				
<i>Micropora</i> , 5 species. ....	*				
"    1 species. ....	...	...	*		
<i>Reptomulticlausa papularis</i> , Mich. ....	...	...	*	*	
<b>BRACHIOPODA.</b>					
<i>Megerlia (Kingena) lima</i> , DeFr. ....	*	...	*	*	*
<i>Terebratella pectita</i> , Sow. ....	*	...	...	*	B

TABLE (continued).

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
BRACHIOPODA (cont.).					
<i>Terebratella Menardi</i> ?, Lam. ....	*	...	...	...	B
<i>Terebratula arcuata</i> , Roem. ....	*	*	*	*	B
<i>biplicata</i> , Sow. ....	*	...	...	...	*
<i>capillata</i> , d'Arch. ....	...	...	*	*	...
<i>ovata</i> , Sow. ....	L	...	...	*	...
<i>Terebrirostra lyra</i> , Sow. ....	*	...	...	*	B
<i>Rhynchonella convexa</i> , Sow. ....	*	...	...	*	B
<i>dimidiata</i> , Sow. ....	*	...	*	*	*
<i>Grasiana</i> , d'Orb. ....	*	*	...	*	?
<i>Schloenbachi</i> , Dav. ....	*	*	*	...	...
<i>Lamarckiana</i> , d'Orb. ....	...	...	Le	...	...
LAMELLIBRANCHIATA.					
<i>Ostrea canaliculata</i> , Sow. (= <i>O. lateralis</i> , Nills.).	*	*	*	*	*
<i>carinata</i> , Sow. ....	*	...	*	*	*
<i>hippopodium</i> , Nilss. ....	...	*	...	...	...
<i>Lesueuri</i> , d'Orb. ....	L	...	...	*	*
<i>vesicularis</i> , Lam. ....	*	*	*	*	*
<i>vesiculosa</i> (var.) ....	...	*	*	...	...
<i>Exogyra conica</i> , Sow. ....	*	*	*	*	*
<i>Rauliniana</i> , d'Orb. ....	*	*	*	*	*
<i>Pecten asper</i> , Lam. ....	*	*	*	*	B
<i>elongatus</i> , Lam. ....	*	...	...	...	*
<i>Galliennii</i> , d'Orb. ....	*	...	...	*	B
<i>orbicularis</i> , Sow. ....	...	...	*	...	*
<i>Puzosianus</i> , d'Orb. ....	*	...	...	*	...
sp. 1 ....	*	...	*	*	...
sp. 2 ....	...	...	*	...	...
<i>Janira quinquecostata</i> , Sow. ....	*	*	...	*	*
<i>quadriscopata</i> , Sow. ....	*	*	...	...	...
<i>æquicostata</i> , d'Orb. ....	*	*	*	*	...
<i>Lima cenomanensis</i> , d'Orb. ....	...	*	...	*	...
<i>clypeiformis</i> , d'Orb. ....	L	*	...	...	...
<i>simplex</i> , d'Orb. ....	...	...	*	...	...
<i>semiornata</i> , d'Orb. ....	...	...	*	*	...
<i>Inoceramus striatus</i> , Sow. ....	*	*	*	...	*
<i>Spondylus striatus</i> , Sow. ....	*	*	*	*	*
<i>Mytilus ligeriensis</i> , d'Orb. ....	...	*	...	...	...
<i>Trigonia spinosa</i> , d'Orb. = <i>Vicaryana</i> ....	*	...	*	...	*
<i>crenulata</i> , Lam. ....	...	...	*	...	...
<i>Arca ligeriensis</i> , d'Orb. ....	...	...	...	...	B
<i>Corbis rotundata</i> , d'Orb. ....	...	...	*	...	B
<i>Cytherea plana</i> ?, Sow. ....	...	...	*	...	...

TABLE (continued).

	NORMANDY.			ENGLAND.	
	A	B	C	D	E
	La Hève and St. Jouin.	Near Orbiquet.	Vimoutiers and Lisores.	Warminster Greensand.	Lower Chalk.
<b>LAMELLIBRANCHIATA. (cont.).</b>					
<i>Cytherea</i> , sp. (small) .....	...	...	*	*	B
<i>Cardium Hillanum</i> , Sow. ....	...	...	*	..	B
<i>Cyprina ligeriensis</i> , d'Orb. ....	...	*	*		
<b>GASTEROPODA.</b>					
<i>Avellana cassis</i> , d'Orb. ....	*	...	*	...	*
<i>Aporrhais</i> , sp. ....	*				
<i>Fusus Espaillaci</i> , d'Orb. ....	...	...	Le		
<i>Natica gaultina</i> , d'Orb. ....	*	...	...	..	*
<i>Pleurotomaria Archiaci</i> , d'Orb. ....	L				
" <i>Mailleana</i> , d'Orb. ....	L	...	...	*	*
" <i>perspectiva</i> , Mant. ....	L	...	...	*	*
" sp. ....	*	...	Le		
<i>Turboidea</i> , sp. ....	*				
<b>CEPHALOPODA.</b>					
<i>Ammonites varians</i> , Sow. ....	*	*	*	*	*
" var. <i>Coupei</i> , Brongn. ....	*	...	...	*	*
" <i>Mantelli</i> , Sow. ....	*		*	*	*
" <i>navicularis</i> , Mant. ....	*	...	...	*	*
" <i>falcatus</i> , Mant. ....	*	...	*	*	*
" <i>rotomagensis</i> , Brongn. ....	...	...	*	*	*
" <i>cenomanensis</i> , d'Arch. ....	...	...	*	...	*
<i>Hamites simplex</i> , d'Orb. ....	...	...	Le	...	*
" sp. ....	*				
<i>Turrillites costatus</i> , Lam. ....	*	...	*	...	*
" <i>tuberculatus</i> , Bosc ....	*	...	*	...	*
<i>Baculites baculoides</i> , d'Orb. ....	...	...	*	*	*
<i>Scaphites æqualis</i> , Sow. ....	*		*	...	*
<i>Nautilus elegans</i> , Sow. ....	...	...	Le	...	*
" <i>subradiatus</i> , d'Orb. ....	L	...	...	*	*

## VIII. SUMMARY AND CONCLUSIONS.

It is now recognized by the Geological Survey of Great Britain that the Gault and Upper Greensand can no longer be regarded as separate stages or chronological divisions of the Cretaceous System. To speak of 'the Gault' as a formation distinct from and older than 'the Upper Greensand' is simply a mistake, for there can be no doubt that what is called Upper Gault in the East of England is



coeval with Upper Greensand in the west. They are merely different lithological facies of one group of deposits, and in the systematic classification of the future a new name will have to be found for this combined Gault-and-Greensand formation. It is much more developed in England than in France, and its name should be taken from some English locality.

On the other hand, we claim to have shown in this paper that when we pass from the Upper Greensand to the Lower Chalk we find that the change in the nature of the deposit corresponds with a great change in the fauna. This change is particularly conspicuous in Dorset and the Isle of Wight, where the base of the Chalk is always marked by the abundance of ammonites belonging to the species *varians*, *Coupei*, *curvatus*, and *Mantelli*, with *Turrilites tuberculatus* and *T. Morrisii*.

It is true that in Wiltshire there is a more gradual passage from Greensand to Chalk, and that some of these cephalopods do appear in the sand just below the Chloritic Marl, but this only shows that where the record is more complete we find a few forerunners of the Chalk Marl fauna coming in locally before the time when these species spread over the whole marine province.

We are, therefore, very decidedly of opinion that in England there is only one plane of division in this series of beds which can possibly be taken as separating one natural group of deposits from another. Further, seeing that England and Northern France formed part of one and the same area of deposition, we should be much surprised if a change of conditions which introduced a new assemblage of cephalopoda over the whole of Southern England did not show itself just as clearly in the North of France.

Before passing over to France, however, we described the sections to be seen in the cliffs of East Devon, where the Chalk Marl is represented by glauconitic and quartziferous limestones, rich in fossils and yielding an assemblage of species which more closely corresponds with the Cenomanian fauna of the Sarthe than with any other local English fauna. Moreover, the position of these beds is perfectly clear, for they are plainly marked off from the Upper Greensand, which is at the same time fully developed, and they are overlain by a complete Middle Chalk or Turonian stage. Here, therefore, on English ground we have a diminutive 'Cenomanian' deposit, part of which has an arenaceous character and a peculiar shallow-water fauna connecting it very closely with the typical Cenomanian of the Sarthe.

Our next study was that of the fine section exposed in the cliffs near Havre (Seine Inférieure). Our object was simply to see and decide for ourselves how much of it corresponded to the Gault-and-Greensand stage and how much to the Lower Chalk. We have indicated what seem to us the obvious and natural divisions of the series near Havre, and have pointed out that our interpretation of the section agrees closely with that of M. Lennier, who has studied and described it more carefully than any other French geologist.

The fact that the same bed is taken both by M. Lennier and by

ourselves as without doubt the base of the 'Cénomanien' is sufficient to prove that this base is a clearly-marked horizon. Now it seemed to us equally clear that this basement-bed corresponded to the Chloritic Marl of the Isle of Wight, or zone of *Stauronema Carteri*. The overlying beds are therefore the equivalent of our Chalk Marl, and the material of them is a chalky marl, though more visibly glauconitic than our Chalk Marl. At a certain level there is a bed which has some resemblance to Totternhoe Stone, and above this *Holaster subglobosus* becomes common, just as it does in some parts of England. About 80 feet from the base is a band of glauconitic chalk with phosphate-nodules, but there is no marked change of fauna here, and between 30 and 40 feet above this band we reach the base of the Turonian.

In our opinion, therefore, the acknowledged 'Cénomanien' of these cliffs is the equivalent of our Lower Chalk, and of that only. That its fauna should contain a certain admixture of species which lived in English waters at the very close of the Upper Greensand epoch can only surprise those who imagine that every portion of a contemporaneous set of beds must hold precisely the same fauna, whether one portion was formed in shallower water or not. The presence of *Pecten asper* and other fossils which do not occur in our Chalk Marl is capable of a very simple explanation, which we shall mention further on.

Beneath this 'Cénomanien' at Cape La Hève there is a representative of our Gault-and-Upper Greensand group. It is of no great thickness, only about 35 feet, unless the basal conglomerate or Carstone be added, as M. Lennier thinks it should, which would raise the total to 50 feet. In this thickness, however, the Lower Gault (or Albien proper), together with so much of the Upper Greensand as is included in the zone of *Ammonites rostratus* (or Gaize), are clearly represented, but we do not think that any equivalent of the English zone of *Pecten asper* is present. This zone is so variable a quantity in England that there is nothing surprising in its being absent at Havre, where the whole Gault-and-Greensand group is evidently in process of thinning out.

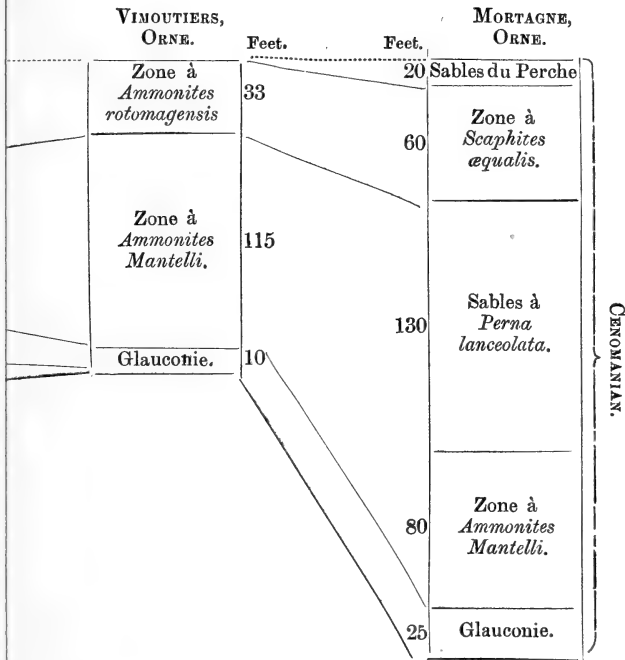
We have seen that on the south coast of England the zone of *Pecten asper* varies from 60 to about 6 feet, and north of Devizes, in Wiltshire, it thins rapidly till we get a sequence very like that near Havre, namely Chloritic Marl with phosphates resting on a few feet of unfossiliferous marly greensand which passes down into micaceous sandstone or Gaize. Moreover this zone is absent at Eastbourne, Folkestone, and Wissant, and also in Argonne and Perthois on the borders of the Marne and Meuse in the East of France, the Chloritic Marl in all these places resting directly on beds which are referred to the zone of *Ammonites rostratus*.<sup>1</sup>

Passing now to the Cenomanian of the Calvados and Orne, a section near Honfleur seems to show the Chloritic Marl with a somewhat different facies, for it no longer contains phosphatic nodules,

<sup>1</sup> See Barrois, 'Terr. Crét. des Ardennes,' Ann. Soc. géol. Nord, vol. v. (1878) p. 332.

[To face p. 172.]

SECTIONS.





COMPARISON OF ENGLISH AND FRENCH SECTIONS.

(Scale: 1 inch = 100 feet.)

ISLE OF WIGHT. Feet.		EASTBOURNE. Feet.		ST. JOUIN AND CAP LA HÈVE. Feet.		VINOUTIERS, ORNE. Feet.		MORTAGNE, ORNE. Feet.	
LOWER CHALK.	Blocky Chalk.	86	Blocky Chalk.	88	Firm Chalk with Cherts.	45	Zone à <i>Ammonites rotomagensis</i>	33	20 Sables du Perche
	Chalk Marl.	120	Chalk Marl.	7 100	Glaucinitic Chalk with Cherts.	75	Zone à <i>Ammonites Mantelli</i> .	115	60 Zone à <i>Scaphites æqualis</i> .
	Chert Beds.	4 27	Micaceous Sandstone.	4 36	Gaize.	3 26	Glauconie.	10	130 Sables à <i>Perna lanceolata</i> .
	Grey and Yellow Sands and Sandstones.	85	Sandy Clay and Gault.	Thickness unknown.	Gault.	10			80 Zone à <i>Ammonites Mantelli</i> .
	Sandy Clays and Gault.	145							25 Glauconie.
GAULT AND GREENSAND.									

CENOMANIAN.



but encloses large lumps or doggers of calcareous stone. From this point southward a similar bed or a layer of such glauconitic marly stone seems everywhere to form the base of the Cenomanian.

A section near Lisieux shows the Gault on the point of dying out, and beyond this place what we have called 'the Greensand' forms the base of the Cretaceous series. This is the 'Glaucanie' of M. Paul Bizet, which in the east of the Orne may be 30 feet thick. We believe that the greater part of it corresponds to the Gaize of Havre, but the occurrence of *Pecten asper* in the upper part of it at Notre Dame de Courson, south of Lisieux, suggests the possibility of its also including a thin local representative of the *Pecten asper*-zone. At Vimoutiers, however, the thickness of this 'greensand' is small (only 10 feet), and the only fossil found is *Ostrea vesiculosa*, so that zonal subdivision becomes impossible. The important point is that it lies beneath the bed which we take to represent the Chloritic Marl, and consequently that it is of the age of our Upper Greensand.

At and south of Vimoutiers the Cenomanian proper is divided by French geologists into (1) zone of *Ammonites Mantelli* and (2) the 'Craie de Rouen,' or zone of *Ammonites rotomagensis*. There can be no doubt that these two zones are roughly equivalent to the lower and upper portions of the Cenomanian near Havre and Rouen, and here we are in complete agreement with French geologists.

Lithologically, however, there is a considerable difference between the Cenomanian of Vimoutiers and that of Havre; the lower part has ceased to be a 'craie glauconieuse,' and has become a fine glauconitic and slightly chalky sand, while the upper part has become a still less calcareous and more micaceous sand. Still farther south the lithological differences become more and more marked, till we arrive at the purely arenaceous type of Le Mans.

It is not surprising, therefore, to find that the fauna of these arenaceous beds differs considerably from that of our Lower Chalk and Chalk Marl; the physical and bathymetrical conditions under which these Cenomanian deposits were formed were evidently similar to those under which the highest part of our Upper Greensand was deposited, and hence many of our Upper Greensand molluscs and echinoderms continued to exist in these Cenomanian waters. Besides these, however, there is a certain number of species which are peculiar and do not occur either in our Upper Greensand or in the Chalk Marl, nor in the 'Craie glauconieuse' of Havre; but some of them do occur in the Cenomanian of Devon.

The beds which we have termed the 'Cenomanian of Devon' offer some special points of comparison with that of France, besides the striking resemblance between the two faunas. The minute structure of the bed numbered 11 by Mr. Meyer and of the upper and less arenaceous part of Bed 10 is similar to that of some beds in the lower part of the Cenomanian of Cape La Hève and of Vimoutiers (see p. 140).

Bed 13 of the Devon series has, however, no analogue in France, unless it is to be found in the famous fossiliferous bed near the top

of the Cenomanian at Rouen. We have not seen this bed, but it is described as a glauconitic chalk containing phosphatic nodules and many fossils, among which *Scaphites equalis*, *Baculites baculoides*, *Ammonites navicularis*, and *A. rotomagensis* are common. It is remarkable that phosphatic fossils of these species abound in the bed which overlies No. 12 between Axmouth and Lyme Regis. Some of them are also common in Bed 7 of St. Jouin.

These facts suggest the idea that beds comparable to the upper part of the French Cenomanian, and, like it, containing many phosphatic nodules and casts of fossils, were originally deposited in the Devon area, but were afterwards destroyed by the action of currents, and nothing left of them except the hard phosphatic fossils, with grains of quartz and glauconite, to be embedded as *remanié* material in the beds which overlie the zone of *Ammonites Mantelli*.

Having thus summarized the opinions which we have been led to form from an examination of the rocks and their contents in the West of England and France, we shall conclude by discussing the view which is generally held in the latter country regarding the correlation of the several parts of the two series.

It is on the Cenomanian of Havre that we must concentrate our attention, because when its relative age is settled that of the inland departments will follow as a matter of course. No one now is likely to recur to the view of Prof. Hébert that the Cenomanian sands of the Sarthe are newer than the Craie de Rouen, and that no representative of them exists in Normandy or England.

The view current at the present time among French geologists is that the lower part of the Cenomanian of Havre, as defined by M. Lennier and ourselves, corresponds with the upper part of our Upper Greensand—with so much of it, in fact, as is included by Dr. Barrois in his zone of *Pecten asper*. We cannot find, however, that anyone has yet attempted to indicate how much of the Craie glauconieuse is equivalent to the English Lower Chalk and how much to the zone of *P. asper*.

It is true that Dr. Barrois has expressed his belief that his zone of *Ammonites laticlavus* (our Chloritic Marl) in the East of France corresponds with 'le banc Rotomagien classique de Rouen,'<sup>1</sup> but in answer to our enquiries he informs us that he has no personal acquaintance with the Havre or Rouen sections; that the fossils mentioned in his note were collected for him, and were said to come from the 'Craie de Rouen'; that he had no assurance that they came from Rouen itself; that some of them are preserved in whitish phosphate and some in glauconitic material, and that they may be 'un mélange.' This being so, it is quite possible, as he admits, that some of them were obtained on the coast, and may have come from the very bed which we identify with the Chloritic Marl; in any case, we feel sure that if Dr. Barrois had visited Havre after his

<sup>1</sup> 'Mém. sur le Terr. Crét. des Ardennes,' Ann. Soc. géol. Nord, vol. v. (1878) p. 355.



prolonged study of the Cretaceous rocks of England he would have arrived at the same conclusion as we have.

It is indeed much to be regretted that Dr. Barrois did not carry out his intention of visiting Normandy, for there is no other Frenchman who has so extensive a knowledge of the Upper Cretaceous series in England and France. It would appear that the French have not yet indicated the place of the Craie de Rouen in the coast-section; that is to say, they have not divided this section into a zone of *Ammonites rotomagensis* and a zone of *A. Mantelli*, as at Vimoutiers. As regards its correlation with English sections, the French view rests apparently on three points of similarity between their 'Craie glauconieuse' and our Upper Greensand, such as would naturally strike any one who knew the English Chalk and Greensand only from published descriptions; these are:—

- (1) The large amount of glauconite in the Cénomanien.
- (2) The occurrence of frequent layers of chert.
- (3) The presence of *Pecten asper* and other fossils common in the 'Warminster Greensand.'

We will take these points *seriatim*. (1) It is a mistake to suppose that the material of the 'Craie glauconieuse' resembles that of our Greensand. The very use of the word 'Craie' indicates the difference, and is quite correct in the department of Seine Inférieure, where the matrix does consist of fine chalky matter. Our Upper Greensand, on the contrary, is a sand consisting of quartz and glauconite, though it is sometimes cemented by calcite into a calcareous sandstone.

(2) The occurrence of layers and lumps of true chert does undoubtedly create a superficial resemblance between the two sets of strata; but the researches of Dr. Hinde have so completely proved the connexion between the formation of cherts and the existence of siliceous sponges, that the mere occurrence of cherts can only be taken as evidence of the conditions being locally favourable to the growth of such sponges.

(3) The presence of *Pecten asper* and other fossils, which in England are chiefly found in the Upper Greensand, is the sole argument that requires serious consideration. Let us first of all see what it amounts to when admitted without any qualification. Where does this special fauna exist in England? Certainly not in the Chert Beds either of Wiltshire, Dorset, or the Isle of Wight, which have everywhere a very limited fauna. What are usually called 'the fossils of the Warminster Greensand' have mostly been obtained from a bed of bright green sand (about 10 feet thick) lying above the Chert Beds, and passing up into Chloritic Marl with phosphate-nodules and *Stauronema Carteri*. It is only here, just below the base of the Chalk, that the Chalk Marl cephalopoda make their first appearance in England, and are associated with *Pecten asper* and other fossils which very shortly disappeared from the English part of the Cretaceous sea. It is quite a mistake to suppose that this is a typical Upper Greensand fauna; it is only that of the

very highest bed, so that if two thirds of the French Cenomanian are to be correlated with the thin bed of Greensand near Warminster on the strength of the similarity between the faunas, we must imagine that this thin bed has expanded to a thickness of 80 feet or more in France, although the beds both above and below have very greatly diminished in thickness.

Our lists, however, show that, of the fossils which may be collected from these beds at Havre in a few days' time, quite as many occur in our Chalk Marl as in the Warminster Beds. We suspect that the occurrence of *Pecten asper* has influenced the French systematists more than any other element in the fauna; but our experience in England has convinced us that *P. asper* is very sporadic in its mode of occurrence, and required a very special kind of environment.

We consider it very unsafe to trust to echinoderms or ground-feeding molluscs in correlating at so great a distance apart formations of different lithological character, because the conditions of life may also have been different in the two areas. One condition alone, namely, greater depth of water, might be sufficient to exclude from the one formation species which found a suitable location in the other area. This, we think, is the reason why *Pecten asper* and many other of the Warminster molluscs and echinoderms do not occur in the Chalk Marl, not because they had everywhere ceased to exist, but simply because the water was too deep for them.

The case is quite different with the cephalopoda, for they could move freely from place to place, and were not directly dependent on depth of water or on the nature of the sea-floor. They must therefore be much more trustworthy chronological guides; and if we rely upon their guidance in the present case, we find that they lead us to the very conclusion which we regard as correct, for the cephalopoda of the lower part of the Cenomanian of Havre are identical with those of our Chloritic Marl and Chalk Marl, and they do not occur in the Chert Beds of our Upper Greensand.

Let us now take another point of departure, and consider what modifications are likely to present themselves in our Chalk Marl when traced into shallower water and nearer to a line of coast. If we examine the Chalk Marl of the Isle of Wight under the microscope, we find that it actually is a Craie glauconieuse; it consists essentially of minute grains of quartz and glauconite, and of shell-fragments embedded in a fine chalky matrix. The material of the corresponding part of the Cenomanian at Havre has less of the chalky matrix, and a larger proportion of the inorganic materials (quartz and glauconite).

There is, in fact, just the difference that one would expect to find in a contemporaneous deposit accumulated rather nearer to the land, and we have shown that this change gradually increases till the chalky ingredient disappears entirely, and we reach shallow-water sands and sandstones. Would it not be surprising if there were not a corresponding change in the fauna? Is it likely that the same assemblage of fossils would inhabit the littoral sandy floors, the

intermediate depths where glauconitic marls and sands were accumulating, and the comparatively deep water of the Chalk Marl area?

Further, as the period was one of continued subsidence, and as the formation of the Chalk Marl was preceded by that of glauconitic sand in a shallower sea, what is more likely than that the creatures which lived in the shallower sea should gradually migrate to other tracts where the same conditions prevailed, as the area of the sea grew larger, and the central portion of it grew deeper?

Expressed in a few words, our belief is that the 'Cénomaniën' of Havre and Rouen is simply a southern extension of our Lower Chalk, formed in a somewhat shallower part of the sea, rather nearer to a coast-line, and in a locality where conditions were more favourable to the growth of siliceous sponges. Hence it consists of a rather more sandy and glauconitic chalk, with a larger amount of siliceous matter in the form of sponge-spicules and chert-nodules.

We would point out that English geologists have hitherto been obliged to accept the idea of a 'Cénomaniën' which could not be correlated with any one or two divisions of the English Cretaceous series, but was supposed to include a *Pecten asper*-zone which, in England at any rate, had no definite base. Our enquiry relieves them from the necessity of adopting so unsatisfactory a correlation, and substitutes a Cenomanian with a clearly-defined base both in England and France.

As regards what has been termed 'the zone of *Pecten asper*' in England, we think that some other fossil should be chosen as an index of the zone, so as to avoid the confusion which has arisen from the presence of *Pecten asper* at higher horizons in France. Unfortunately cephalopoda are so rare in this zone that it is impossible to select one of that class, and we think that it is best to leave the matter for future consideration.

#### PLATE V.

Cenomanian Ammonites. For Explanation, see text, pp. 156, 157.

#### DISCUSSION.

The PRESIDENT said that any attempt such as the Authors of the present paper have made to correlate any part of the Cretaceous beds of this country with those of the Continent must be hailed with satisfaction by all students of geology; and as the present Authors have given especial attention to this subject, their views deserve the most careful attention from geologists. He invited discussion on the paper that they had just heard read, and asked Mr. Hill whether the floating cephalopoda referred to by him included tetrabranchiata, or were confined to dibranchiata.

Dr. W. F. HUME, in congratulating the Authors on the paper, expressed himself in complete agreement with their conclusions, and remarked on the extreme variation in thickness displayed by the Cenomanian beds exposed in Beer Bay and Hooken Cliff respectively. He also asked whether the Authors would consider the

Chloritic Marl to the westward as younger than the easterly exposures of the same.

Mr. STRAHAN remarked that he was under a disadvantage in discussing the paper, through not having seen the Continental sections referred to. It seemed, however, to be clear that English geologists were having reason to repent the introduction of Continental names into their Cretaceous nomenclature. He himself had always hesitated in using the term 'Cenomanian' from a doubt as to its precise application in this country. The correlation was most important, for the principal break in our Secondary rocks occurs at the base of the Upper Cretaceous group. He enquired if a 'Carstone' and yellow sand which intervened between the Gault and Kimmeridge Clay at Cape La Hève were not the same as the ferruginous grit which forms the base of the Gault in Dorset and elsewhere. Phosphatic nodules occur in the Chloritic Marl and sporadically through the Upper Greensand, and seem to be foreign to the matrix in which they are embedded. The glauconitic grains, too, seem unlikely to have been formed in the water which distributed the sands and coarse grits. He asked the Authors whether they had any clue to the deposits with which these materials had originally been associated. In referring to Mr. Hill's Continental investigations, he congratulated him on a fine piece of work.

Dr. J. W. GREGORY congratulated the Authors on the value of the paper and the greater precision that they have given to a useful term. The confusion in regard to the term 'Cenomanian' is not so much a case of hasty use of a foreign name in England, as of unsatisfactory original definition of the term abroad. He fully agreed with the Authors that echinoids are rather a clue to conditions of formation of a deposit than evidence as to its exact contemporaneity in age.

Mr. R. S. HERRIES hoped that, as a result of this paper, geologists would use the term 'Lower Chalk' in place of 'Cenomanian,' at any rate when speaking of the English beds here described.

Mr. W. HILL, in reply to the President, remarked that they relied on the occurrence of tetrabranchiate cephalopoda to prove the age of the beds, rather than on the fauna which must have existed entirely on the sea-bottom. He thought that the Chloritic Marl of the eastern sections was probably older than that more to the westward. Beds 10, 11, and 12 were certainly seen as far as Branscombe Cliff. He believed that the phosphatized fossils, which Mr. Strahan suggested were derived, were not necessarily so, but might be of the same age as the bed containing them. There were but few phosphatized fossils in the Chloritic Marl of La Hève; and the fact that this marl contained small quartz-pebbles and much sand seemed to him evidence of current-action. He was prepared to admit that the Carstone-like bed seen in the cliffs at Cape La Hève might be of Gault age, and, in conclusion, heartily thanked the Fellows of the Society, on behalf of Mr. Jukes-Browne and himself, for their cordial reception of the paper.

8. *On the SPEETON SERIES in YORKSHIRE and LINCOLNSHIRE.* By  
G. W. LAMPLUGH, Esq., F.G.S., of H.M. Geological Survey.  
(Read January 22nd, 1896.)

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## I. INTRODUCTION.

IN describing the clays which underlie the Chalk at Speeton on the Yorkshire coast in a paper communicated to this Society in 1889,<sup>1</sup> I attempted to show the necessity for a fresh classification of these deposits. Further investigation of this section has fully confirmed the views then advanced. It has also indicated the desirability of a corresponding revision of the inland exposures of the rocks of the same age in Yorkshire and Lincolnshire, since it is only by means of the knowledge of the full sequence to be acquired on the coast-section that the true relationship of the limited and isolated exposures of the interior can be unravelled.

Using such opportunities as have at intervals occurred, I have therefore more or less closely examined the base of the Chalk escarpment throughout its whole length in Yorkshire and Lincolnshire, and desire in this paper to put on record the result of my investigation. It will be shown that the divisions proposed for the Speeton section are readily applicable to the inland exposures, and indeed afford the most convenient and natural means of palæontological classification, albeit some modification of the systems usually applied is thereby required.

It may be well at once to state that, while my chief aim will be to establish the correlation of the deposits by means of their palæontology, no attempt will, for the present, be made to carry the palæontological research further than is necessary for this purpose. Hence the fossils dealt with herein will only partially represent

<sup>1</sup> 'On the Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. pp. 575-618.

the fauna of the various deposits. With the material already collected it would indeed have been possible to present much ampler lists. But the mischief done by the publication of swollen catalogues of hasty determinations, not in these deposits alone, but throughout the whole range of the Secondary rocks, has been so great, and the precise recognition of many of the forms in the present state of their nomenclature is so difficult, that I have thought it advisable to restrict myself as far as possible to the use of those few species which have been adequately described and figured rather than risk adding to the existing confusion.

That the fauna of these rocks has been hitherto much neglected by British palæontologists is no doubt mainly due to the fact that, so far as the British Islands are concerned, it is comparatively restricted both in its occurrence and its interest, the fossils of these marine deposits affording no ready points for comparison with those of the equivalent freshwater strata of the south of England. Over large areas of the continent of Europe, however, as was so clearly shown 25 years ago by Prof. Judd,<sup>1</sup> the conditions of deposit are more directly comparable, and there is a close relationship in the fauna. Recently Prof. A. Pavlow<sup>2</sup> has made a very careful study of the cephalopoda of these rocks with this relationship in view, and his monograph for this branch of the fauna affords a secure basis from which to discuss many questions of stratigraphy and correlation. But not until the rest of the fauna has been taken in hand, and in like manner studied and compared with that of the Continental equivalents of these deposits, will it be possible to compile satisfactory lists of the fossils, or to consider to full advantage the broader aspects of the subject.

## II. FURTHER NOTES ON THE SPEETON SECTION.

In my former paper I proposed to divide the clays of the Speeton section into zones by means of the belemnites, which are by far the most abundant and the most characteristic fossils contained in the deposit.<sup>3</sup> Prof. Pavlow has since shown that each type of belemnite selected for this purpose may be considered palæontologically as a group of allied forms presenting variations of specific value. These variations will no doubt in some cases enable us to trace out minor zones.

<sup>1</sup> 'Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire, etc.,' Quart. Journ. Geol. Soc. vol. xxvi. (1870) pp. 326-348.

<sup>2</sup> 'Argiles de Speeton et leurs Équivalents,' Bull. Soc. Imp. d. Naturalistes de Moscou, n. s. vol. v. pp. 181 & 455 (1891-92). (Also published separately, Moscow, 1892.)

<sup>3</sup> At that time some objection was raised to my selection of the belemnites as the zonal fossils; but, as I then stated, it was quite evident that no other fossils would serve the purpose so well, and I am pleased to find that this statement has been fully borne out and justified by further investigations. As Pavlow has shown, the study of the belemnite-fauna of the epoch is prolific in results throughout Europe. Prof. Dames, in a recent paper, 'Ueber die Gliederung der Flötzformationen Helgolands,' states for that island 'hier wie dort sind die Belemniten die leitenden Fossilien,' Sitzungsber. k. preuss. Akad. Wissensch. Berlin, vol. l. (1893) p. 1031.

Thus *Belemnites pistillirostris* and *B. cristatus* are together more restricted in their range than *B. jaculum*, to which they are closely allied; while *B. Jasikowi* and *B. obtusirostris* similarly occupy a portion only of the zone of *B. brunsvicensis*.

As several of the forms, however, seem to occur indiscriminately throughout the realm of the allied species, I think that for stratigraphical employment, as distinct from their more strictly palæontological study, it will be found serviceable to retain for our present purpose the broader system of nomenclature. It must therefore be understood that in the stratigraphical notes in the following pages the specific names of the zonal belemnites, and to a less extent of the zonal ammonites also, will be freely used in this broader sense, embracing all the closely-allied variations.

Since 1889 I have several times had opportunities for examining exposures of the strata on the foreshore at Speeton, and have been enabled thereby to collect much new palæontological material, and to fix the horizon of a few forms whose exact position had been doubtful. These results, as regards the cephalopoda, are summarized in the Table facing p. 184, where the species as determined by Prof. Pavlow are arranged according to their stratigraphical position.

[On revisiting Speeton while this paper was in the press I had the good fortune to find in the uppermost part of the section, of which our knowledge is still incomplete, among the recent slips under the Chalk escarpment 450 yards south of Speeton Gap, a small strip of brown marly clay, 2 or 3 feet thick, which contained belemnites of a type that I had not hitherto seen at Speeton. In structure, size, and outline this form shows close affinities to *Belemnites jaculum*, but differs markedly from that species in the character of the alveolar extremity: most of the specimens possess a slight lateral groove in the subalveolar region. It seems very probable that this may be the form recorded from Heligoland by Prof. Dames (*op. jam cit.*) as *B. fusiformis*, Voltz, which in that island occupies a zone between the beds with *B. minimus* and those with *B. brunsvicensis*.

I could find no other fossils along with this belemnite, and the band which contained it was bounded on all sides by slips; but below the brown clay was a mass of black pyritous clay with *Ammonites Deshayesii*, and above it dull black clay without fossils such as I have elsewhere seen to occur beneath the marls (A) with *B. minimus*, and there is much likelihood that the slips have preserved the true sequence of the beds.—April 22nd, 1896.]

The reiterated<sup>1</sup> contention of the Rev. J. F. Blake<sup>2</sup> that 'Portlandian' beds may after all exist, as supposed by Prof. Judd,

<sup>1</sup> 'Annals of British Geology for 1892' (London, 1893), Introductory Review, p. xviii.

<sup>2</sup> 'Geology of the Country between Redcar and Bridlington,' Proc. Geol. Assoc. vol. xii. (1891) p. 115.

between the lower Coprolite Bed (E) and the Bituminous Shales (F) of my published section, though it has already been once answered,<sup>1</sup> must here be referred to. The contention is based on a misapprehension of the valuable section published by Leckenby in 1859,<sup>2</sup> for it is beyond doubt that the Bituminous Shales (F of my former paper) are the same strata as the 'Beds Nos. 4 and 5' of Leckenby's section which Blake suggests I may not yet have seen.

These shales have been frequently exposed at Speeton both before and since the publication of my account of the section, and I have carefully examined them to a greater depth than my measurements indicated, since (as stated in my previous paper) the folds into which they are locally thrown, and their position near low-water mark on the foreshore, render detailed work on their lower portion very difficult.

The only beds described by Leckenby that I have not yet had an opportunity of examining are those still lower strata to which he applies the numbers 1, 2, and 3, and assigns a thickness of 30 to 40 feet. The fauna is apparently rather better preserved in these beds than in the compressed shales above, and is of undoubted Kimeridgian age, including *Ammonites* (*Perisphinctes*) *biplex*; *A.* (*Hoplites*) *eudoxus* = *A. evalidus*, Bean MS.; a form near *A. alternans*, labelled *A. Kapfi*, Opp., in some collections; and *Belemnites Troslayanus*, d'Orb.

Specimens from this horizon occur in all the old collections preserved in our public museums, but the only examples that I have myself obtained have been from nodules washed up on the beach. Mr. R. S. Herries, however, has been more fortunate, having some years ago found an exposure of the strata on the foreshore north of Speeton from which he was able to collect all the above-mentioned species, and I have to thank him for his kindness in so readily placing these, with other specimens from his extensive collection, at my disposal. The same horizon seems, as will presently be shown, formerly to have been exposed in one of the clay-pits at Knapton, 14 miles inland.

Our knowledge of the lowermost portion of the Speeton section, below the top of the Upper Kimeridge Shales, must therefore still rest on Leckenby's meagre but probably quite accurate description. I have before pointed out that the so-called 'Middle Kimeridge' and 'Lower Kimeridge' mentioned by Prof. Judd<sup>3</sup> and others<sup>4</sup> as occurring in Filey Bay seem, as now admitted by Blake,<sup>5</sup> to consist entirely of glacially-transported masses of shale, chiefly of Lower Lias age, such as characterize the drift-deposits of this part of the coast.

A well-boring sunk by the Filey Waterworks Company in a field adjoining the railway-station at Filey, after passing through 190 feet

<sup>1</sup> 'Argiles de Speeton,' *op. cit.* 1<sup>re</sup> partie, p. 210; sep. cop. p. 30.

<sup>2</sup> 'Geologist,' vol. ii. p. 9.

<sup>3</sup> 'On the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 240.

<sup>4</sup> J. F. Blake, Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 211.

<sup>5</sup> 'Excursion to the East Coast of Yorkshire,' Proc. Geol. Assoc. vol. xii. (1891) p. 213.



of drift,<sup>1</sup> further penetrated pale-blue sandy clay or shale for 75½ feet before reaching the water-bearing Coralline Oolite. This shale evidently represents the lowest Kimeridgian beds; the only fossil that I was able to obtain from it was an indeterminable fragment of a small slender belemnite, distinct from any of the Speeton species known to me.

In my former paper I described the strikingly sudden change of fauna which takes place at the top of the zone of *Belemnites lateralis*. Immediately below this horizon the prevalent ammonites are the deep-whorled, round-backed forms of the genus *Olcostephanus* and its allies, and the belemnites all belong to the short thick *lateralis*-group, while immediately above it the clays abound in the flat-whorled, square-backed ammonites of the genus *Hoplites* and the slender hastate belemnites of the *jaculum*-type. So complete is this change that I was in doubt when previously describing it whether the apparent mingling of the forms at the junction of the zones in the 'Compound-Nodule Band' (D 1) really indicated contemporaneity, or whether through lack of sedimentation the dead remains of the older fauna had lain uncovered on the sea-floor long enough to become embedded in the same layer with the first relics of the new species.<sup>2</sup> I have, however, since found two specimens of the *lateralis*-type of *Belemnites* (*B. subquadratus*, Roem.) distinctly within the zone of *B. jaculum*, the first in the clay immediately overlying D 1, and the second in the clay 18 inches above that band, which proves that the older type was not quite extinct on the appearance of the newer, though very nearly so.

The researches of Prof. Pavlow on the Speeton fossils have thrown new light on the change at this horizon. He has been able to demonstrate that the incoming fauna was one which had been developed and had prevailed in southern seas, while the displaced fauna was markedly northern in its origin and range.<sup>3</sup> The southern fauna remains almost pure throughout the 'noricus-beds' (C 11 to C 7), but above that zone the *Olcostephani* reappear in a group of species (centring around *Ammonites speetonensis*) which, while distinctly recalling the *Olcostephani* of the upper part of the *lateralis*-zone (D 1 to D 3), are yet so completely modified as to be in every case specifically different. These replace the *Hoplites*-type of ammonites, and though the hastate belemnites (*Belemnites jaculum* and allies) persist much longer, they also eventually disappear, and the field is reoccupied by types (*B. brunsvicensis*) which have probably been derived from ancestors pertaining to the *lateralis*-group.

The line of research thus indicated is still being pursued, and promises to be rich in results bearing on the extent and character

<sup>1</sup> See Mem. Geol. Surv. 'Jurassic Rocks of Great Britain: Pt. I. Yorkshire,' by C. F. Strangways, p. 375.

<sup>2</sup> 'Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 589.

<sup>3</sup> 'Argiles de Speeton,' pp. 93, 188 *et seqq.* (sep. cop.) and 'On the Marine Beds closing the Jurassic and opening the Cretaceous, with the History of their Fauna,' by A. Pavlow, in Bull. Geol. Soc. America, vol. iii. (1892) p. 61.

of the life-provinces of the period and the climatic conditions and changes.

The list of the cephalopoda of Speeton as determined by Pavlow has not hitherto been printed in this country, and is therefore given in the Table facing this page. One or two species whose exact position in the series has been ascertained since 1892 are herein for the first time relegated to their proper zones.

Here I beg leave to thank Prof. A. Pavlow and Messrs. E. T. Newton, F.R.S., and G. C. Crick for their invaluable aid and advice in regard to the palæontology, and Mr. J. W. Stather, for his kindly assistance in various ways in the field, and for the loan of his specimens.

### III. INLAND EXTENSION OF THE SPEETON SERIES IN YORKSHIRE.

The available evidence respecting the inland prolongation of the Speeton clays is very restricted and unsatisfactory.

Prof. Judd<sup>1</sup> mentions their reappearance about a mile distant from the coast in a stream-course near Reighton; but this exposure seems to have been at all times very obscure, and it is now no longer recognizable.

I am informed that clay like that of Speeton was reached in a well sunk a few years ago near Hunmanby Station, 2 miles from the coast; but I could not learn that any fossils were obtained, and there is consequently no means of determining the horizon.

Farther westward the solid rocks at the foot of the steep escarpment of the Chalk are completely hidden by the drift and alluvium of the Vale of Pickering for about 12 miles; but after this interval the steady rise of the base of the Chalk brings the underlying clays above the valley-flat; and there were at one time some small pits in these clays, near the foot of the slope, in the vicinity of the village of Knapton, from which many fossils were obtained. The excavations, however, have been discontinued for half a century, and the sections are now entirely obliterated. A few fossils obtained many years ago from these old pits have been preserved in our public museums, and these furnish certain valuable though scanty indications with regard to the horizon of the deposits. Prof. Judd has supposed<sup>2</sup> that only the lowest members of the Speeton Series are present in this area, and that the 'Middle' and 'Upper' of his divisions of the coast-section have been cut out by the unconformable overlap of the Chalk. But I have elsewhere shown<sup>3</sup> that while the fossils above mentioned indicate the almost

<sup>1</sup> 'Additional Observations on the Neocomian Strata of Yorkshire and Lincolnshire,' Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 327. The clay in question is referred in this paper to the 'Zone of *Ammonites speetonensis*'; but as *Belemnites lateralis* is recorded, which species does not occur in the *speetonensis*-beds, while there is no mention of the occurrence of the characteristic *Belemnites jaculum*, I think that the correlation can scarcely be regarded as established.

<sup>2</sup> *Ibid.* p. 329.

<sup>3</sup> 'The Neocomian Clay at Knapton,' The Naturalist (Leeds), Nov. 1890.

TABLE OF THE CEPHALOPODA OF THE SPEOTON SERIES.

Zone and Bed.	AMMONITES.	BELEMNITES.
A. Passage-marls a.	<i>a</i> <i>Hoplites interruptus</i> ? Brug.	<i>Belemnites minimus</i> , List. — <i>attenuatus</i> , Sow. — <i>ulimus</i> , d'Orb.
B. Zone of Bel. <i>brunsvicensis</i> .	<i>Hoplites Deshayesi</i> , Leym. <i>Amalteus bicurvatus</i> , Mich.	<i>Bel. brunsvicensis</i> , Stromb. (pl. vii. (iv.) figs. 9, 10). — <i>speetonensis</i> , Pavl. (pl. vii. (iv.) figs. 13, 14). — <i>absolutiformis</i> , Pavl. (pl. vii. (iv.) figs. 11, 12). — <i>Jaskowi</i> , Lahnus. (pl. vii. (iv.) fig. 8). — <i>obtusirostris</i> , Pavl. (pl. vii. (iv.) fig. 7).
C1 to upper part of C6.	<i>Olcostephanus</i> ( <i>Simbirskites</i> ) <i>Decheni</i> , Roem. (pl. xviii. (xi.) figs. 4, 5, 6). <i>b</i> — (—) <i>umbonatus</i> , Lahnus. (pl. xviii. (xi.) fig. 8). — (—) <i>discofalcatus</i> , Lahnus. (pl. xviii. (xi.) fig. 2). — (—) <i>speetonensis</i> , Young & Bird (pl. xviii. (xi.) fig. 7). — (—) <i>progreddensis</i> , Lahnus. (pl. xviii. (xi.) fig. 15). — (—) <i>concinus</i> , Phill. (pl. xviii. (xi.) fig. 16). <i>b</i> — (—) cf. <i>Carteroni</i> , d'Orb. — (—) ( <i>Holcoiscus</i> ) <i>rotula</i> , Sow. (see below). <i>b</i> <i>Cyrioceras</i> cf. <i>Matheroni</i> , d'Orb. (pl. xviii. (xi.) fig. 10).	<i>Belemnites jaculum</i> , Phill. (pl. vii. (iv.) figs. 2, 3, 4). <i>o</i> ? — <i>Jaskowi</i> , Lahnus. (see above). — <i>pistillirostris</i> , Pavl. — <i>cristatus</i> , Pavl. (pl. vii. (iv.) fig. 5).
Lower part of C6 and C7.	<i>Olcost.</i> ( <i>Simbirskites</i> ) <i>subnervosus</i> , M. Pavl. (pl. xviii. (xi.) figs. 12, 13). — (—) <i>inversus</i> , M. Pavl. (pl. xviii. (xi.) fig. 14). — (—) <i>Payeri</i> , Tonla (pl. xviii. (xi.) fig. 1). — (—) <i>versicolor</i> ? Trautsch. — (—) ( <i>Holcoiscus</i> ) <i>rotula</i> , Sow. (see below). <i>b</i> <i>Cyrioceras capricornu</i> , Roem. (pl. xviii. (xi.) fig. 9).	
C8 to C11.  Zone of <i>Belemnites jaculum</i> .	<i>Hoplites regalis</i> (Bean), Pavl. (pl. xvii. (x.) figs. 1, 2). — <i>amblygonius</i> , Neum. & Uhl. (pl. xvii. (x.) fig. 6). — <i>oxygonius</i> , Neum. & Uhl. (pl. xvii. (x.) figs. 4, 5). — <i>Bombardi</i> ( <i>mninitus</i> ), d'Orb. (pl. xvii. (x.) fig. 8). — cf. <i>Emblymi</i> , Pict. (pl. xvii. (x.) fig. 7). <i>b</i> ? — <i>heteroptychus</i> , Pavl. (pl. xviii. (xi.) fig. 22). <i>b</i> ? — <i>Morteleiti</i> , Pict. & Lor.	<i>Belemnites subquadratus</i> (rare), d'Orb. (pl. vii. (iv.) fig. 1).



TABLE OF THE CEPHALOPODA OF THE SPEETON SERIES.

Zone and Bed.		AMMONITES.	BELEMNITES.
A. Passage-marls a.	B. Zone of <i>Bel. brunsvicensis</i> .	<i>a Hoplites interruptus</i> ? Brug.	<i>Belemnites minimus</i> , List. — <i>attenuatus</i> , Sow. — <i>ultimus</i> , d'Orb.
		<i>Hoplites Deshayesi</i> , Leym. <i>Amalthus bicurcatus</i> , Mich.	<i>Bel. brunsvicensis</i> , Stromb. (pl. vii. (iv.) figs. 8, 10). — <i>spectonensis</i> , Pavl. (pl. vii. (iv.) figs. 13, 14). — <i>absolutiformis</i> , Pavl. (pl. vii. (iv.) figs. 11, 12). — <i>Jasikowi</i> , Lahus. (pl. vii. (iv.) fig. 8). — <i>obtusirostris</i> , Pavl. (pl. vii. (iv.) fig. 7).
C 1 to upper part of C 6.	Zone of <i>Belemnites jaculum</i> .	<i>Olcostephanus (Simbirskites) Decheni</i> , Roem. (pl. xviii. (xi.) figs. 4, 5, 6). b — (—) <i>umbonatus</i> , Lahus. (pl. xviii. (xi.) fig. 8). — (—) <i>discofalcatus</i> , Lahus. (pl. xviii. (xi.) fig. 2). — (—) <i>spectonensis</i> , Young & Bird (pl. xviii. (xi.) fig. 7). — (—) <i>progreddiens</i> , Lahus. (pl. xviii. (xi.) fig. 15). — (—) <i>concinus</i> , Phill. (pl. xviii. (xi.) fig. 10). b — (—) cf. <i>Carteroni</i> , d'Orb. — ( <i>Holcodiscus</i> ) <i>rotula</i> , Sow. (see below). b <i>Criocerat</i> cf. <i>Matheroni</i> , d'Orb. (pl. xviii. (xi.) fig. 10).	<i>Belemnites jaculum</i> , Phill. (pl. vii. (iv.) figs. 2, 3, 4). c ? — <i>Jasikowi</i> , Lahus. (see above). — <i>distillirostris</i> , Pavl. — <i>cristatus</i> , Pavl. (pl. vii. (iv.) fig. 5).
Lower part of C 6 and C 7.		<i>Olcost.</i> ( <i>Simbirskites</i> ) <i>subinversus</i> , M. Pavl. (pl. xviii. (xi.) figs. 12, 13). — (—) <i>inversus</i> , M. Pavl. (pl. xviii. (xi.) fig. 14). — <i>Payeri</i> , Toulia (pl. xviii. (xi.) fig. 1). — ( <i>Holcodiscus</i> ) <i>versicolor</i> ? Trautsch. — ( <i>Holcodiscus</i> ) <i>rotula</i> , Sow. (see below). b <i>Criocerat capricornu</i> , Roem. (pl. xviii. (xi.) fig. 9).	
C 8 to C 11.	Zone of <i>Belemnites lateralis</i> .	<i>Hoplites regalis</i> (Bean), Pavl. (pl. xvii. (x.) figs. 1, 2). — <i>amblygonius</i> , Neum. & Uhl. (pl. xvii. (x.) fig. 6). — <i>oxygonius</i> , Neum. & Uhl. (pl. xvii. (x.) figs. 4, 5). — <i>Roubaudi</i> ( <i>munitus</i> ), d'Orb. (pl. xvii. (x.) fig. 8). — cf. <i>Euthymi</i> , Pict. (pl. xvii. (x.) fig. 7). b ? — <i>heteroptychus</i> , Pavl. (pl. xviii. (xi.) fig. 22). b ? — <i>Mortelleti</i> , Pict. & Lor. <i>Olcostephanus (Astieria) Astieri</i> , d'Orb. (pl. xvii. (x.) fig. 15). — (—) <i>sulcosus</i> , Pavl. (pl. xviii. (xi.) fig. 18). b ? — (—) <i>Atherstoni</i> , Sharpe (pl. xvii. (x.) fig. 14). b ? — <i>spitiensis</i> , Blanford. — ( <i>Holcodiscus</i> ) <i>rotula</i> , Sow. (pl. xvii. (x.) fig. 11). b <i>Acanthoceras</i> cf. <i>peltoceroideus</i> , Pavl. (pl. xviii. (xi.) fig. 20). b ? <i>Desmoceras</i> cf. <i>cassidoides</i> , Uhl. (pl. xviii. (xi.) fig. 19).	<i>Belemnites subquadratus</i> (rare), d'Orb. (pl. vii. (iv.) fig. 1).
Upper part of D 1.		<i>Hoplites regalis</i> (Bean), Pavl. (see above). — <i>amblygonius</i> , Neum. & Uhl. (see above). — <i>hystrix</i> , Phill. (pl. xvii. (x.) fig. 10). — <i>Roubaudi</i> , d'Orb. (see above). <i>Olcostephanus (Holcodiscus) rotula</i> , Sow. (see above). — ( <i>Polyptychites</i> ) <i>bidichotomus</i> , Leym. (pl. xvi. (ix.) figs. 2, 3, 4).	
Lower part of D 1, D 2, and D 3.	Zone of <i>Belemnites lateralis</i> .	<i>Olcost.</i> ( <i>Polyptychites</i> ) <i>Keyserlingi</i> , Neum. & Uhl. (pl. xvi. (ix.) fig. 1). — (—) <i>gravesiformis</i> , Pavl. (pl. xiii. (vi.) fig. 7). — ( <i>Lamplughii</i> , Pavl. (pl. xiv. (vii.) fig. 1, & xv. fig. 1). — ( <i>ramulicosta</i> , Pavl. (pl. xv. (viii.) fig. 6). — ( <i>Beani</i> , Pavl. (pl. xv. (viii.) fig. 7). b ? — ( <i>triploptychus</i> , Pavl. (pl. xv. (viii.) fig. 4). b ? — ( <i>polyptychus</i> , Keys. (pl. xv. (viii.) fig. 2).	<i>Belemnites lateralis</i> , Phill. (pl. vi. (iii.) fig. 3). — <i>russeus</i> , d'Orb. (pl. vi. (iii.) fig. 7). — <i>subquadratus</i> , d'Orb. (pl. vi. (iii.) fig. 5). — <i>explanatoides</i> , Pavl. (pl. vi. (iii.) fig. 1). d — <i>explanatus</i> ? Phill. (pl. vi. (iii.) fig. 2).
D 4 to D 8.		e <i>Olcostephanus (Craspedites?) fragilis</i> , Trautsch. (pl. xiii. (vi.) fig. 4). e — (—) cf. <i>subditus</i> , Trautsch. (Lincolnshire specimen figured, pl. xiii. (vi.) fig. 5). e <i>Oxyticeras</i> cf. <i>catenulatum</i> , Fisch. [(vi.) fig. 5].	
E. 'Copolite-bed.'	F. Kimeridge Clay. Upper portion.	<i>Olcostephanus (Virgatites)</i> cf. <i>Panderi</i> , d'Orb. (pl. v. (ii.) fig. 5). — (—) cf. <i>scythicus</i> , Michal. (pl. v. (ii.) fig. 7). — (—) cf. <i>Tchernischowi</i> , Michal. (pl. v. (ii.) fig. 6). — (—) cf. <i>dorsoplanus</i> , Michal. (pl. v. (ii.) fig. 4).	<i>Belemnites</i> , cf. <i>absolutus</i> , Fisch. (pl. v. (ii.) fig. 3). — <i>magnificus</i> , d'Orb. (see below).
Lower portion.		<i>Perisphinctes lacertosus</i> , Dum. & Font. (fig. at p. 111, 'Argiles de Speeton'). <i>Olcostephanus (Virgatites)</i> cf. <i>miatchkoviensis</i> , Michal. (pl. iv. (i.) fig. 6).  <i>Hoplites pseudomutabilis</i> , Loriol (pl. iv. (i.) fig. 7). — <i>subundora</i> , Pavl. (pl. iv. (i.) fig. 8). — <i>eudoxus</i> , d'Orb.	<i>Belemnites magnificus</i> , d'Orb. (pl. v. (ii.) fig. 1). — <i>porrectus</i> , Phill. (pl. iv. (i.) fig. 3). — <i>obolicoideus</i> , Pavl. (pl. iv. (i.) fig. 2). — <i>Puzosi</i> , d'Orb. (pl. iv. (i.) fig. 1).  b <i>Belemnites Troslayanus</i> , d'Orb. (pl. viii. (v.) fig. 4).

## Notes on the above Table.

The reference-letters and figures in the first column refer to the beds of the Speeton Clay as numbered in the vertical sections of my former paper (Quart. Journ. Geol. Soc. vol. xiv. 1889, facing p. 618).

The reference in parentheses after the name of the species is given when the species has been figured by Pavlov in 'Argiles de Speeton.'

a. This topmost part of the section was not included by Prof. Pavlov in his table ('Argiles de Speeton', p. 157). The ammonite is in the condition of a compressed cast, but it is evidently a species different from any known to exist in the underlying Zone B, and, so far as can be seen, agrees well in general characters with *Ammonites interruptus*, a Lower Gault form, which has also been found by Mr. W. Hill in the Red Chalk at Withcall, Lincolnshire (Quart. Journ. Geol. Soc. vol. xiv. 1888, p. 324).

b. The species marked thus do not appear in Prof. Pavlov's table, but several of them are described or referred to in the text of 'Argiles de Speeton,' and the others have been determined by him from specimens in my possession. In a few instances the exact horizon of the species has been discovered since the publication of 'Argiles de Speeton,' but where a query (?) is prefixed the true position of the fossil is still more or less conjectural.

c. I have myself found *Belemnites Jasikowi*, both at Speeton and in

Lincolnshire, only in Zone B, but not in Zone C, and the fossil is placed in the latter zone on the authority of Prof. Pavlov.

d. It appears to me doubtful whether this determination can be sustained. The specimen in question certainly agrees very closely with Phillips's species *explanatus*, but it may be no more than an extreme variation of the *explanatoides*-type of *Belemnites lateralis*. If a large number of specimens of this type be compared with a similar number of the Kimeridgian *explanatus*, the difference becomes more apparent than in a single specimen.

e. I have been able to obtain only small and very perishable specimens of ammonites from this horizon at Speeton, and, as Prof. Pavlov admits (*op. cit.* p. 118), such fossils do not lend themselves readily to determination. In the Spilsby Sandstone of Lincolnshire, however, I have collected *Craspedites subditus*, 3 or 4 inches in diameter, and the comparison between these and the Russian specimens of the same size is, very close. I think that the small ammonites in the 'Astarte-bed,' D 4, of Speeton include representatives of the type of *Olcostephanus plicomphalus*, Sow., which abounds in the Spilsby Sandstone.

f. The generic name *Proplanulites*, Teisseyre, is used by V. Uhlig for this group of species (see Neues Jahrb. 1893, vol. i. p. 364).



certain presence of the upper portion of the Speeton Series in the pits, there is no proof of the existence of the lower zones.

The fossils in question are as follows:—

*In the Natural History Museum, South Kensington (in the Bean Collection).*

*Ammonites (Hoplites) Deshayesii*, Leym. One of the specimens bears a label with the MS. name *A. knaptonensis*, Bean.<sup>1</sup>

*Ammonites planus*, Phill., probably the young form of *A. (Amaltheus) bicurvatus*, Mich. I have recently found the same form at Speeton similarly associated with *Hoplites Deshayesii*.

? *Ammonites (Hoplites) regalis*, Pavl. It is doubtful whether this is really a Knapton species. Two small unlabelled specimens are contained in a tray with other fossils marked 'Knapton,' but in appearance they closely resemble Speeton specimens and differ from the Knapton fossils.

*In the Woodwardian Museum at Cambridge.*

*Terebratulina Martiniana*,<sup>2</sup> d'Orb.; labelled *Terebratulina striata*.

*In the Museum of the Scarborough Philosophical Society.*

*Pholadomya (Martini)*, Forbes?; in a rather crushed condition.

To these we may also add the following species recorded by Prof. J. Phillips in his 'Geology of the Yorkshire Coast' (3rd ed. p. 242):—

*Hamites maximus* (mentioned in 1st edition only).

*Waldheimia faba*, d'Orb.

*Rhynchonella lineolata*, Phill.

Some further evidence on the subject is afforded by the description of one of the Knapton pits given in 1822 by Young and Bird in their 'Geological Survey of the Yorkshire Coast,' which reads as follows (2nd ed. p. 62):—

'In one of the clay-pits at Knapton we see the junction of the shale with the red and grey chalk. The clay, where it joins the chalk, is soft and plastic; and this, also, is the case with the lower part of the chalk. The two substances are partly blended together; the soft chalk, which occurs here of both colours, approaching to the state of red or grey clay; while the clay that is next the chalk is somewhat impregnated with calcareous matter, and is almost divested of its schistose quality. The same facts are observed in the specimens from the Staxton boring, and at the junction of the chalk and shale in the lower part of the Speeton cliffs.'

This description implies a gradual passage of the Red Chalk into the underlying clay, and is quite opposed to Prof. Judd's view that there is an unconformable overlap of the base of the Chalk at this

<sup>1</sup> From a reference to this species in Young and Bird's 'Geological Survey of the Yorkshire Coast,' I should, however, judge that the name was originally applied by Bean to the ammonite next on the list, namely, *A. planus*, Phill., since the fossil is classed with the *Nautili*, and described as follows:—'A minute flat shell, remarkably smooth, with a small umbilicus and a slight keel, occurs in the upper shale. It resembles some of the ammonite family, and Mr. Bean has named it *A. knaptonensis*' (2nd ed. 1828, p. 272).

<sup>2</sup> I am indebted to Mr. J. F. Walker, M.A., for this determination.

point. The marly passage-beds seem to be exactly similar to those which, as Young and Bird remark, exist at the same horizon at Speeton.<sup>1</sup> The section is now entirely hidden, but near a spring which issues from the base of the Red Chalk at the eastern side of Knapton Plantation, less than 200 yards distant from the largest of the old pits, I have found several fragments of belemnites, trampled out of the clayey subsoil by sheep, and these appear all to belong to the stout variety of *B. minimus* (perhaps = *B. subfusiformis* of some authors), which abounds in the passage-marls at Speeton.

A well-boring at East Heslerton, 2 miles farther east, according to the account given in the Geological Survey Memoir,<sup>2</sup> also passed through 'red clay' immediately below the Chalk, probably denoting the presence of similar passage-marls.

As will presently be shown, the evidence of the western wold-scarp, both in Yorkshire and in Lincolnshire, is likewise in agreement with this interpretation of the Knapton section.<sup>3</sup>

In the more westerly of the Knapton pits, on the slope almost due south of Knapton Hall, the clay seems to have belonged to an horizon altogether lower and not, strictly speaking, referable to any part of the true Speeton Series, a portion of the Kimeridge Clay some little depth below the top being, I think, here represented. I found in one of these old pits a large limestone concretion containing fossils, evidently similar to the septaria referred to by Prof. Judd,<sup>4</sup> which had presumably been rejected when the clay was excavated. This nodule yielded several identifiable fragments of ammonites, which I have every confidence in referring to the well-known Kimeridge species *Ammonites (Hoplites) eudoxus*, d'Orb., a form known, as mentioned on a previous page, to the old collectors as *A. evalidus*,<sup>5</sup> Bean MS. Phillips also records *Rhynchonella inconstans*, Sow., from the 'Kimeridge Clay, Knapton' ('Geology of Yorkshire,' 3rd ed. 1875, p. 243).

There is, therefore, much probability that we have in this clay the equivalent of 'Bed No. 3' of Leckenby's Speeton section, and that the horizon is well below the summit of the Kimeridgian strata.

Owing to the slipped state of the escarpment on these slopes, it is scarcely possible to make any safe estimate of the thickness of the clay between this pit and the base of the Chalk, but it cannot be great; so that whatever higher beds of the Kimeridge Clay may

<sup>1</sup> 'On the Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 602.

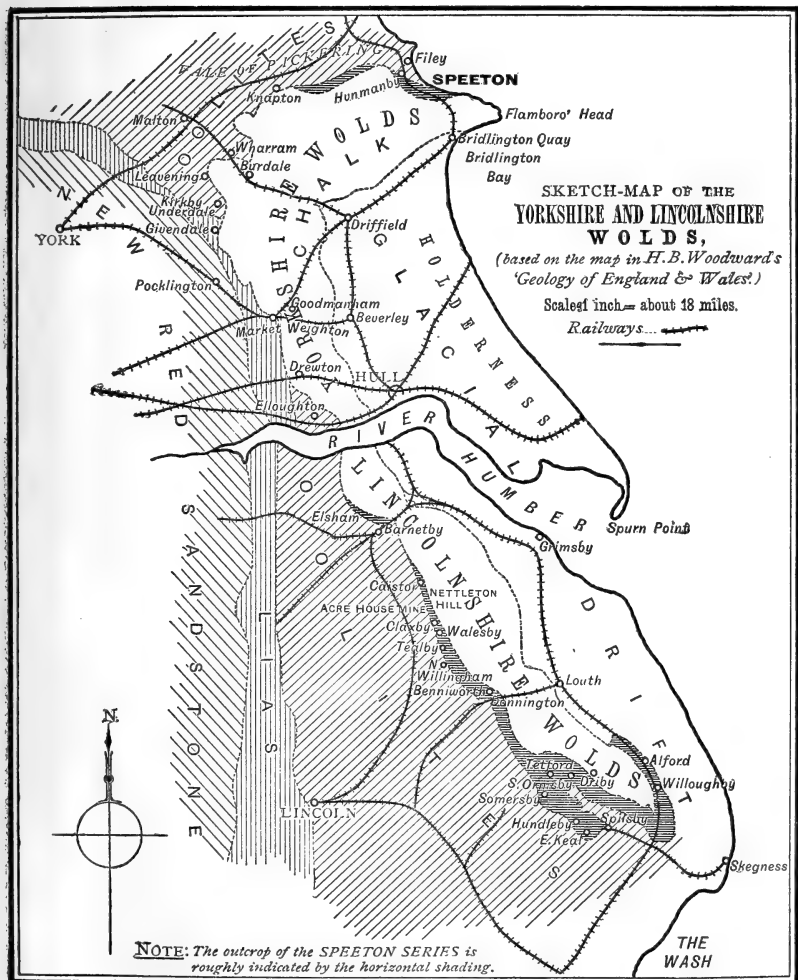
<sup>2</sup> Mem. Geol. Surv. 1880, 'Oolitic and Cretaceous Rocks south of Scarborough,' p. 26.

<sup>3</sup> In Heligoland a similar sequence obtains (see Dames, 'Ueber die Gliederung der Flötzformationen Helgolands,' Sitzungsber. k. preuss. Akad. Wissensch. Berlin, vol. I. 1893, p. 1032), and here also no evidence seems to be forthcoming for the existence of the lowest beds of the Speeton series.

<sup>4</sup> Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 328.

<sup>5</sup> Prof. Judd mentions the occurrence of this ammonite at Knapton, but considers it (in his later work) as equivalent to *A. fascicularis*, d'Orb., a Lower Cretaceous species, from which, however, it differs in many respects (see a remark as to this in my former paper, Quart. Journ. Geol. Soc. vol. xlv. 1889, p. 613).





exist, along with all that remains of the Speeton Series, are here contained within a very narrow compass. Somewhere in this vicinity the final thinning-out of the latter must occur, as we find that in going westward from Knapton all trace of the Speeton Series is almost immediately lost, and the Red Chalk, also attenuated, appears to rest directly on the Kimeridge Clay.

From the absence for several miles of any further section revealing the character of the clays immediately beneath the Chalk, it is rather unsafe to assert positively that no clay except the Kimeridge exists in this position, but no proof to the contrary is forthcoming. Four miles west of Knapton the hitherto westerly trend of the Wold escarpment is rather suddenly changed for a southerly or south-south-easterly direction, which persists up to, and beyond, the Humber, to the end of the Wolds in Lincolnshire. In the neighbourhood of the bend the character of the base of the Red Chalk undergoes an important alteration, by which, instead of presenting a gradual passage into the clays, it assumes a pebbly or conglomeratic aspect,<sup>1</sup> and preserves this character in a greater or less degree throughout the whole extent of its course along the western margin of the Yorkshire and Lincolnshire Wolds. Some information regarding the underlying clays may be gleaned from the old spoil-heaps of the Burdale tunnel on the Malton and Driffield railway. The northern end of this tunnel has been excavated for some distance in the clays, and has cut their junction with the Chalk. Such fossils as I have been able to recognize among the débris are all Kimeridgian forms, and none proper to the Speeton Series have been found. Fragments of belemnites are rather abundant, apparently referable mostly to the Kimeridgian species *B. explanatus*, Phill., with perhaps also *B. Troslayanus*; and an imperfect specimen of the former species was obtained from the clay in the banks of the little stream at Wharram Percy. It seems clear that in this region elevation and erosion were going on contemporaneously with the steady deposition of muddy sediment in the submerged area to the eastward, and that these conditions continued to prevail until the setting-in of that slow and persistent depression which brought about the accumulation of the great Chalk-formation.

Along the western margin of the Yorkshire Wolds the pebbly base of the Red Chalk is generally the only relic of this period, but in a few places the conglomeratic band thickens locally into a sandy deposit resembling the Carstone of Lincolnshire, and like it separable from the overlying Red Chalk.<sup>2</sup> Of this the best example known to me occurs at the head of Scotten Dale, the deep valley east of Kirby Underdale, 13 miles E.N.E. of York.<sup>3</sup> In this locality

<sup>1</sup> See W. Hill, 'On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire,' Quart. Journ. Geol. Soc. vol. xlv. (1888) pp. 334-35.

<sup>2</sup> J. F. Blake, Proc. Geol. Assoc. vol. v. (1877) p. 245.

<sup>3</sup> The Rev. J. F. Blake seems to have been the first to call attention to this interesting section, see Geol. Mag. 1874, p. 363, and *op. jam cit.* p. 246. See also C. F. Strangways, Geol. Surv. Mem. 'The Geology of the Country N.E. of York and S. of Malton,' p. 25.

at the time of my last visit the following section could with some difficulty be made out on the steep southern side of the vale:—

	Ft.	In.
White chalk not well exposed.		
6. Hard, pinkish and yellowish, nodular chalk ..... seen for about	2	0
5. Deep-red and yellowish nodular chalk. <i>Belemnites minimus</i> and fragments of <i>Inoceramus</i> abundant ..... seen for about	2	0
4. Soft, shaly, red chalk ..... about	0	3
3. Hard, gritty, nodular red chalk. <i>B. minimus</i> abundant.....	1	0
2. Yellow clayey marl with ferruginous grains. <i>B. minimus</i> and <i>Terebratula</i> , sp. were found at this horizon apparently in place; but the conditions suggested a slight possibility of their having been washed down from the overlying red chalk.....about	1	0
1. Coarse, pebbly, ferruginous sand of deep-brown colour well seen for	3-6	
Total thickness probably about 12 feet. Pebbles range up to 2 inches in diameter, composed of oolitic ironstone and phosphatized nodules, with small black shining 'lydites,' quartz-grains, etc.		
Dark blue clay, referred to the Upper Lias. <sup>1</sup>		

In this section the marly layer, No. 2, which appears to contain sparingly certain characteristic Red Chalk fossils, distinctly suggests a passage downward from the Red Chalk into the underlying unfossiliferous ferruginous sands; and the latter deposit so closely resembles the Lincolnshire Carstone in its general appearance and in its relationship to the Red Chalk that I think we may unhesitatingly accept the Rev. J. F. Blake's proposal that it should be correlated with the Carstone.

Mr. W. Hill has suggested<sup>2</sup> that the character of the base of the Red Chalk in general may be explained as resulting from the 'working up' of the underlying material during its deposition. But I think that in the above section, as at Knapton and at Speeton, there is good evidence for an actual downward passage at this horizon. The Yorkshire sections are thus in agreement with those of Lincolnshire, in which county, as Mr. A. Strahan has shown,<sup>3</sup> there is everywhere the closest stratigraphical relationship between the Red Chalk and the underlying Carstone, often with clear proof of a gradual passage from one to the other.

Traces of deposits similar to that of Scotten Dale occur in various places both north and south of this locality, as at Wharram,<sup>4</sup> Leavening,<sup>5</sup> Givendale<sup>6</sup>, etc., but always of greatly reduced thick-

<sup>1</sup> Mem. Geol. Surv. 'Country N.E. of York and S. of Malton,' p. 10.

<sup>2</sup> W. Hill, Quart. Journ. Geol. Soc. vol. xlv. (1888) pp. 338, 355.

<sup>3</sup> A. Strahan, 'On the Relations of the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 486, also Mem. Geol. Surv. 1888, 'Country around Lincoln,' p. 105. In these opinions Mr. A. J. Jukes-Browne does not concur (Mem. Geol. Surv. 1887, 'East Lincolnshire,' p. 15, footnote). After examining most of the Lincolnshire sections, however, I am convinced that Mr. Strahan's views on this matter are correct.

<sup>4</sup> J. F. Blake, Proc. Geol. Assoc. vol. v. (1877) p. 245.

<sup>5</sup> W. Hill, Quart. Journ. Geol. Soc. vol. xlv. (1888) p. 341.

<sup>6</sup> J. F. Blake, Geol. Mag. 1874, p. 362.

ness and insufficiently exposed for study. In its still more attenuated form, as the pebbly basement-layer of the Red Chalk, it was revealed a few years ago in the railway-cutting of the Market Weighton and Driffield branch east of Goodmanham, being here of very coarse texture, with fragments of phosphatic stone and coarsely-gritty oolitic iron-ore, up to 3 or 4 inches in diameter. In this vicinity the unconformability at the base of the Upper Cretaceous rocks reaches its extreme stage, the underlying strata being shaly limestone of Lower Lias age; and in going farther south we find that the higher members of the Jurassic series emerge again in succession.

In the extensive cuttings near Drewton, 4 miles north of the Humber, on the Hull and Barnsley railway, the base of the Red Chalk was at one time excellently exposed, and is still partially visible. These sections while still fresh were examined by Messrs. W. Keeping and C. S. Middlemiss, who record the following details<sup>1</sup> :—

	Feet.	Inches.
Nodular red chalk .....	1	6
Pale nodular chalk .....	1	3
Clayey red chalk .....	0	6
Grey nodular chalk .....	1	0
Red chalk .....	0	3
Yellow-green clay .....	0	9
Unctuous red clay .....	1	6

resting on a 'dark, almost black clay, slightly shaly . . . probably the Kimeridge Clay, but characteristic fossils were not obtained.'

It has been suspected that the uppermost portion of the dark clays beneath the above may represent some portion of the Speeton Series,<sup>2</sup> and the clayey character of the base of the Red Chalk seems to favour the supposition. But a careful search has failed to reveal any evidence of the presence of the Speeton fauna, the first fossils met with below the Red Chalk being, as Messrs. Keeping and Middlemiss pointed out, undoubtedly Jurassic forms, including *Belemnites abbreviatus* and *B. Owenii*. On general considerations, however, it seems just possible that some of the unfossiliferous clay immediately below the Red Chalk may represent the sparingly fossiliferous marls with *Belemnites minimus* (A) which have been shown to occupy this horizon at Speeton and Knapton, though, as one of the cuttings still exhibits traces of a pebbly band at the base of the Red Chalk, it is more likely that the Speeton Series is entirely absent at this point.

Nearer the Humber, in a small pit in the dale north of Elloughton, the Red Chalk is seen to contain numerous small pebbles, and probably has a similar pebbly base, the underlying deposit again being dark clay, supposed to be Kimeridge Clay.

<sup>1</sup> 'On some New Railway Sections and other Rock-Exposures in the District of Cave, Yorkshire,' Geol. Mag. 1883, p. 218.

<sup>2</sup> A. Harker, 'The Oolites of the Cave District,' The Naturalist (Leeds), 1885, p. 231.

The sum of the available evidence regarding the inland extension of the Speeton Series in Yorkshire indicates, therefore, that these rocks undergo a rapid attenuation as a whole in a westerly direction, and that all disappear within 14 miles of the coast except the uppermost division (*Belemnites minimus*-marls: Zone A), which persists as the pebbly or clayey basement-layer of the Red Chalk, swelling locally into a thicker deposit of ferruginous sand akin to the Lincolnshire Carstone.

The data are insufficient to prove whether the Lower Cretaceous Clays end off against the edge of their basin of deposition, and are simply overstepped by the Upper Cretaceous strata; or whether a true unconformability, as in so many other parts of the country, is developed in them at this horizon. That erosion took place in the western part of the district before the deposition of the Red Chalk is indeed certain; but it is not certain that the clays of the coast-section ever extended so far westward.

#### IV. THE SPEETON SERIES IN LINCOLNSHIRE.

##### a. General Observations and Bibliography.

With respect to the Lincolnshire sections my present purpose has regard for the sequence of the rocks rather than for their local stratigraphy; and as the whole area has been recently examined and reported upon by the officers of the Geological Survey, whose maps and memoirs<sup>1</sup> afford all the necessary information bearing on the mode of occurrence and extent of the various strata to be considered, it will be neither requisite nor desirable that I should reiterate such details. My aim therefore will be to give the broader outlines only of the general stratigraphy, but to enter more fully into the palæontological and other evidence which may afford the means for the correlation of the rocks in question with the more easily classified clays of the Speeton section. And indeed, though during the course of my field-work in this area I have gone repeatedly over the whole extent of the Lower Cretaceous outcrop, I have concentrated my attention chiefly on such places as promised the best palæontological results. The most suitable localities for this purpose have proved to be the broken escarpment near Acre House, with its abandoned iron-ore workings; the limestone-pits of Normanby, Walesby, Tealby, and Willingham; the fine railway-cutting sections on either side of Donnington-upon-Bain; and the brickyards and sand- and sandstone-pits of the Spilsby district.

Of the palæontological material collected only a small portion can be adequately dealt with at present, but fortunately the cephalopoda are sufficiently abundant and characteristic to allow of definite

<sup>1</sup> Sheets (one inch) Nos. 86, 84, and 83. Memoirs, 'North Lincolnshire and South Yorkshire' (Sheet 86); 'Country around Lincoln' (Sheet 83); and 'East Lincolnshire' (Sheet 84).

conclusions being drawn respecting the correlation of these Lincolnshire deposits with the Speeton Series of the Yorkshire coast, thereby clearing away certain prevalent misconceptions and providing a safer basis for future discussion of their age and origin.

These beds seem to be unrepresented at the northern extremity of the Lincolnshire Cretaceous escarpment, the pebbly base of the Red Chalk in the vicinity of the Humber resting, so far as is known, directly on the Kimeridge Clay.<sup>1</sup> About 6 miles south of that estuary, however, thin sands and clays intervene for a short space between the Kimeridge Clay and the Chalk, but are not well exposed, and are soon again altogether lost beneath the overlapping Chalk. They reappear in stronger force after a further interval of about 5 miles; and thenceforward, from the neighbourhood of Caistor, are continued southward, gaining steadily in importance, up to the southern termination of the Chalk escarpment, 8 miles north of the Wash, where the drift and alluvium of the low ground enshroud them.

Where best developed the diverse lithological characters of this series have afforded a ready and simple method of subdivision which has been adopted by all its investigators. These divisions are shown in the Table printed on p. 194, in which the results of previous workers are stated and compared.

In addition to the papers mentioned in the Table, Mr. H. Keeping gave in 1882 a short but valuable account of the series,<sup>2</sup> and especially of the sections on the Louth and Lincoln railway, now in great part obscured, from which he had in 1872 secured a large collection of fossils. His classification is essentially that of Prof. Judd and the earlier observers; but he seems to have been the first to call attention to the band of phosphatic nodules at the base of the Spilsby Sandstone, and his fossil lists are in many respects in advance of those of his predecessors, though herein, as in all the other palæontological lists of the area yet published, the confusion of *Belemnites brunsvicensis* with *B. lateralis*,<sup>3</sup> and the vagueness of the specific names employed for the ammonites, seriously impair their value as aids to the correlation of the deposits.

The detailed comparisons of the Speeton section with the Lincolnshire deposits previously put forward are shown in the Table facing this page.<sup>4</sup>

<sup>1</sup> A. Strahan, 'On the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 489.

<sup>2</sup> H. Keeping, 'On some Sections of Lincolnshire Neocomian,' Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 239.

<sup>3</sup> The same error pervades nearly all the fossil-lists given by Prof. Judd and the Survey, and also affects the Continental lists in Judd's paper in Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 326.

<sup>4</sup> The correlation given in the late Mr. W. Keeping's 'Fossils, etc., of Upware and Brickhill' (Cambridge, 1883), p. xi, is omitted, being practically a reproduction of that of Prof. Judd. There is also a brief correlation by Mr. A. J. Jukes-Browne in his paper 'On the Application of the term Neocomian' (Geol. Mag. 1886, p. 311), based upon Prof. Judd's account of the Speeton sections.

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alistes de Moscou,

G. W. Hiles de Speeton et leurs équivalents,' pt. iii., Bulletin  
shire Moscou, vol. v. n.s. pp. 181 & 455. 1891-92.  
et le

LINCOLNSHIRE.			LINCOLNSHIRE.
	Zone		
ches sablonneuses su- rieures (upper sands) présentant l'Aptien, à partie remanié.	.....		
caire de Tealby à <i>Pec- n cinctus</i> et <i>Belemnites micanaliculatus</i> .	ZONE F nnites		Calcaire de Tealby.
ile de Tealby à <i>Oleo- ephanus speetonensis</i> .		cheni	
	ZONE	versus	Argile de Tealby.
		Astieria	Partie supérieure de la roche ferrugineuse de Claxby à <i>Hopl. regalis</i> et <i>Bel. jaculum</i> .
che ferrugineuse de axby à <i>Hoplites nori- s</i> .		vesifor- lis, etc.	Partie inférieure de la roche ferrugineuse de Claxby à <i>Olcostephanus Blaki</i> , <i>Belemnites russiensis</i> , etc.
	ZONE (incl)	ragilis,	Grès de Spilsby à <i>Olcostephanus subditus</i> .
es de Spilsby avec <i>Be- mnites lateralis</i> , Phil. <i>orpulentus</i> , Nik.), et <i>Olcostephanus stenom- katus</i> .			
ortlandien inférieur, struit à l'époque de la ormation du grès de pilsby.)		rrectus,	Schistes à <i>Discina latissima</i> et à ammonites écrasées.
giles schisteuses avec ucella Pallasi, <i>Peri- hinctes Quenstedti</i> , et autres péricrinides imprimés.	ZONE Ki	lis.	Schistes Kimméridgiens.
uches à <i>Hoplites eu- xus</i> , <i>H. pseudomuta- lis</i> , et <i>Exogyra virgula</i> .			





COMPARISONS OF THE YORKSHIRE AND LINCOLNSHIRE INFRA-CRETACEOUS STRATA BY THE VARIOUS AUTHORS UNDERMENTIONED.

J. W. Judd in 'Additional Observations on the Neocomian Strata,' etc., Quart. Journ. Geol. Soc. vol. xxvi. p. 331. 1870.

Geological Survey in 'The Geology of the Country around Lincoln' (Explan. of Sh. 83), p. 88. 1888.

A. Pavlow in 'Études sur les Couches Jurassiques et Crétacées de la Russie,' Bulletin de la Soc. Imp. des Naturalistes de Moscou, p. 55. 1889.

G. W. Lamplugh in 'On the Speeton Clays and their Equivalents in Lincolnshire,' Abstract in Report Brit. Asson. 1890, p. 803, also in 'Argiles de Speeton et leurs équivalents,' Moscow, p. 210. 1891.

A. Pavlow (Pavlow & Lamplugh) in 'Argiles de Speeton et leurs équivalents,' pt. iii., Bulletin de la Soc. Imp. des Naturalistes de Moscou, vol. v. n.s. pp. 181 & 455. 1891-92.

\* See footnote on p. 193.

	YORKSHIRE.	LINCOLNSHIRE.	YORKSHIRE (Speeton).	LINCOLNSHIRE.	ZONES.	YORKSHIRE.	LINCOLNSHIRE.	SPEETON, YORKSHIRE.	ACRE HOUSE, LINCOLNSHIRE.	SPEETON.	LINCOLNSHIRE.	
GAULT. (Albien, d'Orb.)	Hunstanton Red Rock.	Hunstanton Red Rock.						Red Chalk.	Red Chalk.			
	UNCONFORMITY.							ZONE A.—Marls with <i>Belemnites minutus</i> .	Carstone.			
UPPER NEOCOMIAN. (Aptien, d'Orb., Rhodanien and Aptien, Renev.)	? Black clays ..... } Dark blue clays ... } 'Cement-beds' ..... }	ft. 120 30	Upper Sands?	Absent.	Carstone, with derived Neocomian fauna.	Z. à <i>Hoplites Deshayesi</i> .	Couches à <i>Hoplites Deshayesi</i> de Speeton (Néoc. supérieur de Judd).	Roches sablonneuses supérieures (upper sands) représentant l'Aptien, en partie remanié.	Tealby Limestone.	B.—Zone à <i>Hoplites Deshayesi</i> et <i>Belemnites brunsvicensis</i> .	Calcaire de Tealby.	
MIDDLE NEOCOMIAN. (Urgonien, d'Orb., Barremien & Urgonien, Coq.)	Dark blue clay with few fossils ('zone of <i>Pecten cinctus</i> ') ..... Blue clays with fossils (' <i>Ancylloceras</i> -beds') ..... Clays with septaria...	80 40 30	'Tealby Series.' Clays, limestones, and oolitic ironstones. With many fossils.	Upper Middle Lower Speeton Clay.	Tealby Beds. Tealby Limestone. Tealby Clay. Claxby Ironstone. Spilsby Sandstone.	Z. à <i>Pecten cinctus</i> . (Les ammonites sont encore peu étudiées.)	Couches à <i>Pecten cinctus</i> (large var.), <i>Ancylloceras Duvalii</i> , <i>Meyeria ornata</i> .	Calcaire de Tealby à <i>Pecten cinctus</i> et <i>Belemnites semicanaliculatus</i> .	Tealby Clay.	C 1 to C 6.—Zone à <i>Olcostephanus Dapeni</i> et <i>speetonensis</i> . C 6 and C 7.—Zone à <i>Olcostephanus subquereus</i> et <i>Belemnites jaculum</i> . C 8 to C 11.—Zone à <i>Hoplites regalis</i> ; <i>Astieria Astieri</i> (type); <i>B. jaculum</i> .	Argile de Tealby.	
LOWER NEOCOMIAN. (Néocomien, d'Orb., Valanginien & Néocomien, Desor.)	Blue clays ('zone of <i>Ammonites speetonensis</i> ') ..... Blue clays ('zone of <i>A. noricus</i> ') ..... Blue pyritic clays ('zone of <i>A. Astierianus</i> ') .....	100 50 50	Lower Sands and Sandstones?			Z. à <i>Olcostephanus versicolor</i> et <i>O. fasciatofalcatulus</i> .	Couches à <i>Olcostephanus speetonensis</i> ( <i>concinus</i> et <i>venustus</i> ) et <i>Belemnites Jasikowi</i> , Lah.	Argile de Tealby à <i>Olcostephanus speetonensis</i> .		Zone C.—Zone of <i>Belemnites jaculum</i> .	Claxby Ironstone.  Spilsby Sandstone.	D 1 to D 3.—Zone à <i>Olcostephanus grapesiformis</i> , <i>O. Keyserlingi</i> ; <i>Belemnites lateralis</i> , etc.
	Blue clays ('zone of <i>Ammonites speetonensis</i> ') ..... Blue clays ('zone of <i>A. noricus</i> ') ..... Blue pyritic clays ('zone of <i>A. Astierianus</i> ') .....	100 50 50	Lower Sands and Sandstones?			Z. à <i>Hoplites noricus</i> ( <i>amblygonius</i> ) et <i>Belemnites jaculum</i> (type).	Couches à <i>Hoplites noricus</i> et <i>Belemnites jaculum</i> , Phill. (type).	Rouge ferrugineuse de Claxby à <i>Hoplites noricus</i> .	Zone D.—Zone of <i>Belemnites lateralis</i> (including Zone E, Coprolite-Bed).	Claxby Ironstone.  Spilsby Sandstone.		D. 4 to D. 8.—Zone à <i>Olcostephanus fragilis</i> , cf. <i>subditus</i> , etc.
	Blue clays ('zone of <i>Ammonites speetonensis</i> ') ..... Blue clays ('zone of <i>A. noricus</i> ') ..... Blue pyritic clays ('zone of <i>A. Astierianus</i> ') .....	100 50 50	Lower Sands and Sandstones?	Z. à <i>B. lateralis</i> ( <i>corpulentus</i> ) et <i>Olcost. stenophthalmus</i> . Portlandien supérieur.	Couches à <i>B. lateralis</i> Phill. ( <i>corpulentus</i> , Nik.), <i>Olcostephanus subditus</i> , <i>Orynoticeras catenulatum</i> .	Grès de Spilsby avec <i>Belemnites lateralis</i> , Phill. ( <i>corpulentus</i> , Nik.), et <i>Olcostephanus stenophthalmus</i> .		Claxby Ironstone.  Spilsby Sandstone.	'Coprolite-Bed.'			
TITHONIAN, <i>Oppel</i> .	UNCONFORMITY.										Couches F à <i>Belemnites magnificus</i> , <i>porrectus</i> , et à ammonites écrasées.	Schistes à <i>Discina latissima</i> et à ammonites écrasées.
JURASSIC.	Portlandian Clays, etc.	Kimeridge Clay.						Zone F.—Bituminous shales (Upper Kimeridge of English geologists).	Upper Kimeridge Shales.	Couches à <i>Hoplites pseudomutabilis</i> .	Schistes Kimméridgiens.	
	</											



The scheme first proposed by Pavlow in 1889, after his preliminary study of the fossils of the deposits, and afterwards more fully stated and slightly amended in 1891-92, is substantially that which I brought before the British Association in 1890, and reproduced in 'Argiles de Speeton et leurs Équivalents' in 1891; and between this and the propositions of the previous workers there are radical differences.<sup>1</sup> Further investigation has fully confirmed the correlation suggested by Pavlow and myself, and it is now sought to place on record the field-evidence, not heretofore published, by which the comparison is sustained. Amid the general discussion of this evidence some side-issues will be debated which are of much consequence to the right understanding of the relations of the series as a whole. The deposits will be considered in their upward stratigraphical sequence.

### b. The Kimeridge Clay.

In comparing the Yorkshire and Lincolnshire areas we possess in the Kimeridge Clay an admirable base-line.

Though, owing to the crushed condition of the fossils in both districts, the list of recognizable species in common is short, the general similarity in position and composition is so close that no reasonable doubt can exist that the bituminous shales<sup>2</sup> which underlie the Spilsby Sandstone everywhere to the southward of Caistor in Lincolnshire are the equivalents of the similar shales (Zone F) underlying the 'Coprolite-bed' (Zone E) of the Speeton section, and were laid down in the same basin of deposition.

It is indeed possible that the uppermost portion of this deposit may have been locally removed by erosion in certain areas in Lincolnshire previous to the deposition of the Spilsby Sandstone, since the researches of the Geological Survey have gone to show that there is a definite unconformable overlap of that rock in the northern part of the county;<sup>3</sup> and the absence, so far as is yet known, of the large belemnites of the *Owenii*-group (*Belemnites magnificus*, *Puzosi*, etc.), which occur at Speeton at the top of the bituminous shales, may perhaps be thus accounted for. These fossils are, however, by no means common even in the shore-exposures at Speeton, and it may well be that their apparent absence in Lincolnshire arises only from the lack of good collecting-ground at this horizon.

<sup>1</sup> With respect to the Geological Survey publications, it is to be noted that the Lincolnshire deposits containing *Belemnites lateralis* are fully described in the recently-published Mem. Geol. Surv., 'The Jurassic Rocks of Great Britain,' vol. v. (pp. 286 *et seqq.*), and the corresponding portion of the Speeton Clay in vol. i. (Yorkshire) of the same series, and this seems to imply an acceptance of the views of Prof. Pavlow respecting their age, though no very definite opinion is in either case expressed. See second division of Table of comparisons.

<sup>2</sup> For further information regarding the Kimeridge Clay, see J. F. Blake, Quart. Journ. Geol. Soc. vol. xxxi. (1875) pp. 196-233; T. Roberts, *ibid.* vol. xlv. (1889) pp. 545-560, and Geol. Surv. Mems., *jam cit.*

<sup>3</sup> Mem. Geol. Surv. 1888, 'The Country around Lincoln' (Sheet 83), p. 82.

*Subdivisions of the Infra-Cretaceous Strata in Lincolnshire according to the several Observers undermentioned.*

Geological Survey.

'East Lincolnshire,' Mem. Sheet 84. 1887; 'Country around Lincoln,' Sheet 85. 1888; and 'North Lincolnshire, etc.,' Sheet 86. 1890.

J. W. Judd.

'On the Strata which form the base of the Lincolnshire Wolds,' Quart. Journ. Geol. Soc. vol. xxiii. (1867) p. 227, and 'Additional Observations, etc.,' Quart. Journ. Geol. Soc. 'vol. xxvi. (1870) p. 326.

W. H. Dikes and J. E. Lee.

'Outlines of the Geology of Nettle-ton Hill, Lincolnshire,' Mag. Nat. Hist. 2nd ser. vol. i. (1887) p. 561.

Ed. Bogg.

'Outlines of the Geology of the Lincolnshire Wolds,' Trans. Geol. Soc. ser. 1, vol. iii. (1816) p. 392.

Red Chalk.	Hunstanton Red Rock. —— (unconformity) ———	Red Chalk.	'Stratum No. 2' (lower part of).
Carstone.	Upper Ferruginous Sands.	The Thoresway Sand.	'No. 3.' — A coarse, brown, pebbly sand without organic remains.
Upper Ironstone and Clay, Tealby Limestone = 'Roach', Ironstone in Sh. 84. Tealby Clay.	Tealby Series { Tealby Limestone and Clay. Oolitic Ironstone.	The Grey-stone.  { 'A mass of small, globular, shining grains of a dark brown colour, cemented together by ferruginous matter.'	'No. 4.' — Nearly equal proportions of oolite limestone and calcareous clay of a lightish grey colour, etc.
Spilshy Sandstone (with pebble-bed of derived phosphatic nodules at the base).	Lower Sands and Sandstone. —— (unconformity) ———	The Greensand and Sandstone.	'No. 5.' — Stratum of quartz-grains, sometimes conglomerated into sandstone, and then containing fossils.
Kimeridge Clay.	Kimeridge Clay.	Kimeridge Clay.	'No. 6.' — A shale stratum, bituminous, pyritous, and calcareous.

But, with this reservation respecting the uppermost part, we may safely state the general equivalency of the Upper Kimeridge deposits of Yorkshire and Lincolnshire.

### c. The Basement-bed of the Spilsby Sandstone.

The base of the pale greenish or reddish quartzose sand or sandstone which overlies the Kimeridge Clay everywhere in Lincolnshire southward of Caistor is marked by the presence of numerous dark phosphatic nodules, usually from 1 to 3 inches in diameter.

At Speeton there is at the same horizon a similar though more compact band of 'coprolites' (Zone E), and in this respect the two areas are distinctly comparable. These nodules, first noticed as above mentioned, by Mr. H. Keeping in a railway-cutting near South Willingham, were afterwards traced by the officers of the Geological Survey over an extended area,<sup>1</sup> and by them were considered to be derivative pebbles marking the destruction of pre-existing deposits. It appears to me, however, that the derivative character of these nodules is exceedingly doubtful, this view being liable to the same objections as apply under similar circumstances at Speeton.<sup>2</sup>

The composition of the so-called pebbles tells strongly against their derivative origin. Wherever I have been able to examine them they have been of uniform character, without admixture, and have all presented the same dark phosphatic exterior and eroded aspect. But in many instances when broken open they reveal a gritty interior not unlike that of the overlying sandstone, and when dissolved in acid they leave an abundant residue of somewhat coarse quartzose sand, which distinctly suggests their original accretion in a sandy matrix like that now enclosing them, and is not to be reconciled with the idea that they were once concretions in the Kimeridge Clay. Moreover at Speeton, where the nodules are enclosed in pyritous clay, the only residue obtained on dissolving them is a little dark fetid mud with groups of angular pyrites-crystals and a very little fine sandy silt. They occur in both localities mostly in the form of more or less obscure casts of shells and portions of the whorls of ammonites, sometimes riddled with the tube-like cavities of boring molluscs; and these fossils, when recognizable, are distinctly not such as characterize the subjacent strata or any other deposit of a lower horizon now existing in the areas. The specific determination of these casts is of course full of difficulty and uncertainty, as is shown by the state of the lists published in the Geol. Surv. Mems.<sup>3</sup> from the collection made in Lincolnshire by Messrs. A. J. Jukes-Browne and M. Staniland. The lists contain a total of nineteen determinations; but in only eight

<sup>1</sup> Mem. Geol. Surv. 1888, 'The Country around Lincoln,' pp. 89 *et seqq.*, and *ibid.* 1887, 'East Lincolnshire,' pp. 15 *et seqq.*

<sup>2</sup> 'Subdivisions of the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 586.

<sup>3</sup> 'East Lincolnshire,' p. 139; 'Country around Lincoln,' p. 93.

instances is the species stated, the remainder giving the genus alone. Moreover a footnote is added to the lists expressing great hesitancy in the identifications. The following are the fossils mentioned:—

SPECIES: *Terebratula ovoides*, Sby., *Waldheimia Woodwardii*, *Myacites recurva*, *Lucina portlandica*, Sby., *Thracia Phillipsii*, Roem. (or *depressa*, Sby.), *Ammonites biplex*, Sby., *A. plicatilis*, and *A. speetonensis*, Y. & B.

GENERA: *Arca*, sp., *Astarte*, *Cyprina*, *Cucullæa*, sp., *Isocardia*?, *Lima*, sp., *Pectunculus*, sp., *Trigonia*, sp., *Natica*, sp., *Pleurotomaria*, sp., *Belemnites*, sp.

In discussing this list we may at once dismiss the genera, remarking only that the rotund form of the casts, the presence of the impression of both valves in the case of bivalves, the absence of fragments of oysters and other characteristic hard fossils occurring abundantly in the underlying strata, and the general facies of the assemblage, are all points which tell against the derivative origin of the nodules. But when we turn to the consideration of the species above-mentioned, we do not find any better evidence in support of the statement that 'there can be no doubt that most of the phosphates have been derived from the Kimeridge Clay' ('East Lincolnshire,' p. 139). *Terebratula ovoides*, Sby., if it be the species mentioned by Mr. W. Keeping,<sup>1</sup> has been found in blocks supposed to have been derived from the Spilsby Sandstone, and also in a phosphatized condition at Upware, Brickhill, and Potton, and therefore if the species be rightly determined the evidence is entirely against its derivative character. *Waldheimia Woodwardii*, Walker, is not known to exist in rocks of a lower horizon. *Myacites recurva* is referred to at the foot of the list as being a form which 'might equally well be *Panopæa neocomiensis*; and on the other hand *Thracia Phillipsii* may well be *Th. depressa* of the Kimeridge Clay.' *Lucina portlandica* occurs commonly at Speeton as a cast in the 'Coprolite-bed' (Zone E), and appears to be confined to this horizon both in Yorkshire and Lincolnshire. *Ammonites biplex*, as the name is usually applied in England, is almost without determinative value even when the specimens are well preserved, since almost every round-whorled ammonite with bifurcating ribs, from whatever horizon, has in turn received the title, whether it be of the genus *Perisphinctes* or *Olcostephanus* or what not. In some of our public collections, for example, specimens from the Upper Kimeridge have been mixed with others undoubtedly from the 'Zone of *Ammonites speetonensis*' of the Speeton Clay under the common name of *A. biplex*.<sup>2</sup> *A. speetonensis* stands in exactly similar case, being a much-abused species into which it has been the fashion of English palæontologists to thrust almost any form of the genus *Olcostephanus* that had the misfortune to be found anywhere between the base of the Red Chalk and the top of

<sup>1</sup> W. Keeping, 'Fossils of Upware, etc.,' Cambridge, 1883, pp. 34-37.

<sup>2</sup> See Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 613. The last-mentioned form, *Ammonites concinnus* of Phillips, is recognized by Pavlow as including *Olcostephanus* (*Simbirskites*) *subinversus*, M. Pavl., and other allied species.

the Kimeridge Clay. *A. plicatilis*, another 'difficult species,' is usually considered an Oxfordian and Corallian form, and under the circumstances the value of the determination is altogether doubtful. These fragments of ammonites are in fact similar to those occurring abundantly in the 'Coprolite-bed' (E) of Speeton in like preservation, which Prof. Pavlow has studied and illustrated in 'Argiles de Speeton' (pl. ii. & pp. 114 and 115), and considers to be the relics of a fauna not otherwise represented in the section. The species he has identified from Speeton are given in the Table of Cephalopoda facing p. 184. Thus we see that both the composition of the nodules and their fossils tell strongly in favour of their original accretion at their present horizon.

The weakness of the fossil evidence for their derivative character was evidently felt by the writer of the 'East Lincolnshire' memoir, who therefore puts forward the further suggestion that 'it is just possible that there were certain older Neocomian beds (destroyed before the deposition of the Spilsby Sandstone), and that some of the casts were derived from them.' But as it will presently be demonstrated that the Spilsby Sandstone represents the lowest horizon of the Speeton Clay (which has been shown by recent researches to be older than any known Neocomian rocks and more closely allied to the Jurassic than to the Lower Cretaceous), and as the palæontological evidence demonstrates that there are no beds missing at this horizon in Lincolnshire which occur in Yorkshire, where, if my reading of the section be correct, there is practically an unbroken record from Jurassic to Upper Cretaceous times, it is difficult to believe that the supposed beds can ever have existed in the area.

Except in one particular, the nodule-bed of Lincolnshire is indeed in all respects analogous to the 'Coprolite-bed' of Speeton, the difference being that while the latter occurs as a band in the midst of a conformable clayey or shaly series, and does not mark any striking lithological change, the former is developed along a very important stratigraphical horizon at which the great clayey series of the Middle and Upper Jurassics gives place to the coarse sandy deposit forming the Spilsby Sandstone, a change evidently betokening a wide-reaching revolution in the physical conditions of the region. There seems moreover, as already stated, to be evidence of actual erosion and unconformability at this horizon as we approach the Humber,<sup>1</sup> and it is therefore the more remarkable that the nodule-bed should not contain better indications of the destruction of the older strata if any 'pebbles' were really derived therefrom. But all the arguments which at Speeton<sup>2</sup> tell in favour of the formation of these phosphatic stones as nodules contemporaneous with the deposit have equal strength in Lincolnshire. In both districts the stones, though most abundant at a definite horizon, are by no means confined to it, but occur at other levels,

<sup>1</sup> See Geol. Surv. Mem. 1888, 'Country around Lincoln,' p. 82.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 584.

or sparsely scattered throughout the series; they contain certain fossils proper to the bed in which they occur; and their eroded surfaces show less appearance of rolling than of corrosion from the attack of various destructive organisms inhabiting the sea-floor, whose activity is similarly manifest on the undoubtedly indigenous fossils of the deposits.

The subject thus raised has broad bearings, and if my view be correct there are many localities other than those now in question where a revision of the evidence for the derivative character of the 'phosphate-stones' is desirable. I am satisfied, for instance, from a recent examination at Hunstanton of the mode of occurrence of *Hoplites Deshayesi* and other fossils thus preserved towards the base of the Carstone, that these are proper to the deposit and not derivative;<sup>1</sup> and a study of the literature relating to the 'phosphate-beds' at Potton, Wicken, Upware, etc.,<sup>2</sup> shows that most of the investigators of these localities have found it necessary to allow that some at any rate of the nodular material is not older than the bed in which it occurs.

It is not my purpose, however, to pursue the wider question on this occasion,<sup>3</sup> and I shall content myself for the present by restating my conviction, based on a careful study of the various types of nodules and concretions marking the different horizons of the Speeton Clay, that some of these, including the dark phosphatic stones, have gathered in the mud of the sea-bottom, and have formed hard masses before the accumulation of the overlying strata,<sup>4</sup> and that the comparative rarity or abundance of concretions of this type affords a rough measure of the rate of deposition of the enclosing material.

The investigations of the *Challenger* expedition<sup>5</sup> have taught us that the formation of nodules both of phosphate and manganese is still taking place in areas of slow deposition beneath our existing oceans, and from the description given of the former they appear to agree remarkably in shape, size, and general characters with those under consideration. It is true that the conditions are in many respects not analogous, but the phenomena are probably, none the less, closely illustrative of those of our Jurassic and Cretaceous seas, wherein the marine sediments seem to have been characterized by

<sup>1</sup> See reference to these in W. Keeping's 'The Fossils of Upware and Brickhill,' Cambridge, 1883, p. 57.

<sup>2</sup> Among other works see J. J. H. Teall, 'The Potton and Wicken Phosphatic Deposits' (Cambridge, 1875); W. J. Sollas, Quart. Journ. Geol. Soc. vol. xxix. 1873, p. 76; W. Keeping, *op. jam cit.* p. 17. See also the discussion between Walker, J. F. (Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. 1866, pp. 31 & 381, and xx. p. 118), and H. G. Seeley (Ann. & Mag. Nat. Hist. ser. 3, vol. xviii. p. 111, and xx. p. 23); and O. Fisher, Quart. Journ. Geol. Soc. vol. xxix. (1873) p. 52.

<sup>3</sup> For an excellent summary of our knowledge on this subject, with extensive bibliography, see R. A. F. Penrose, Jun., 'Nature and Origin of Deposits of Phosphate of Lime,' Bull. U.S. Geol. Surv. vol. vii. no. 46 (1888), p. 475.

<sup>4</sup> At the meeting of the Geol. Soc. previous to that at which this paper was read, Messrs. A. J. Jukes-Browne and Hill put forward a very similar explanation for the phosphatized fossils and nodules of the 'Cénomanien.'

<sup>5</sup> *Challenger* Reports, 'Deep-Sea Deposits' (London, 1891), p. 391.



an exceptionally high percentage of phosphoric acid.<sup>1</sup> After such nodules were formed a local increase in the strength of the current appears often to have wafted away the matrix, and the harder matter was thus exposed to the corrosive action of the sea-water and its denizens, producing on the nodules a misleading appearance of wave-erosion.

As to the length of the pause in the sedimentation denoted by these bands of nodules, we can judge only from the evidence of other regions where the interval is more fully represented, or from the change to be noted in the fauna of the strata above and below such bands. In this particular instance Prof. Pavlow, as already mentioned, believes that an ammonite-zone well developed in Russia is at Speeton condensed into these 4 inches of nodular matter.

#### d. The Spilsby Sandstone.

The lithological and stratigraphical characters of this deposit have already been sufficiently indicated. Where it occurs in the condition of a loose sand the fossils exist only in the form of obscure hollow casts; but it usually consists in part of irregular concretionary masses, often extremely hard, in which fossils are frequently abundant, though difficult to extract and sometimes injured by crushing. The most prominent feature of the fauna is the abundance of the bivalve mollusca, mainly referable to the genera *Pecten*, *Pinna*, *Lima*, *Trigonia*, *Panopæa*, etc., many of which are well preserved. But a glance at the published lists<sup>2</sup> will suffice to show the uncertain state of the nomenclature, and as it is not in my power at present to give more precise information regarding these fossils, I do not propose herein to discuss them further than to state that I can recognize among them some forms which occur at Speeton in the 'Pale Beds' (D 6 and 7) of the zone of *Belemnites lateralis*, and that several species could be matched, I think, in the Hartwell Clay and equivalent Jurassic strata farther south.<sup>3</sup>

<sup>1</sup> Considering the clear evidence which we now possess of the alternating encroachments of a northern and a southern fauna into certain parts of the North European basin during the epoch of the formation of the rocks between the Kimmeridge Clay and the Chalk, and the plentiful occurrence of phosphatic nodules where the northern and southern faunas meet, in the compound-nodule band, D 1, at Speeton, the following passage in the *Challenger* Report relative to the mode of occurrence of the recent nodules is at least worth noticing (p. 396):—'It may be pointed out that phosphatic nodules are apparently more abundant in the deposits along coasts where there are great and rapid changes of temperature, arising from the meeting of cold and warm currents, as, for instance, off the Cape of Good Hope and off the eastern coast of North America. It seems highly probable that in these places large numbers of pelagic organisms are frequently killed by these changes of temperature, and may in some instances form a considerable layer of decomposing matter on the bottom of the ocean.'

<sup>2</sup> Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 140; H. Keeping. Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 241; Geol. Surv. Mem., 'Jurassic Rocks of Great Britain,' vol. v.

<sup>3</sup> [Since this paper was read, Prof. Pavlow has described and figured *Aucella volgensis*, Lahus., and *Aucella volgensis*, var. *radiolata*, Pavl., both found in the 'zone of *Ammonites stenomphalus*' in Russia, from the Spilsby Sandstone of Donnington (see p. 215).—April 22nd, 1896.]

The cephalopoda are decidedly less abundant than the lamelli-branchiata, but fortunately are still sufficiently numerous and characteristic to provide safe grounds for the correlation. The belemnites are widely, though scantily, distributed, and all the specimens yet discovered are of the *lateralis*-type (*Belemnites explanatoides*, Pavl.; *B. lateralis*, Phill.; *B. russiensis*, d'Orb.), forms occurring in the lower part of Zone D at Speeton.

The ammonites, though less rare, are not, as a rule, well preserved. They have been referred by English palæontologists to various species of obscure antecedents, such as *Ammonites plicomphalus*,<sup>1</sup> Sby.; *A. mutabilis*, Sby.; *A. Koenigii*, Sby.; *A. rotundus*, Sby.; all names more or less vaguely applied in England, but usually to Jurassic forms. More recently Pavlow<sup>2</sup> has identified, among other species, *Olcostephanus (Craspedites) subditus*, Trautsch., a well-known Continental form of great value in the correlation. At Speeton the corresponding horizon appears to be found in beds 5, 6, and 7 of Zone D. These are almost devoid of identifiable ammonites,<sup>3</sup> but the correlation is, I think, well established by the belemnites, combined with the evidence of the overlying and underlying strata. I have no doubt that, when the remaining branches of the fauna have been more thoroughly studied, a relatively large number of the species will be found to be common to the two areas.

It is very probable, however, as will presently appear, that the upper boundary of the Spilsby Sandstone is not everywhere of exactly the same age, the accumulation of sandy material having persisted longer in some localities than in others.

### e. The Claxby Ironstone.

The paucity of sections in the Lincolnshire area is especially detrimental when we attempt to deal with this deposit and the overlying Tealby Clay. In the neighbourhood of Caistor, and for

<sup>1</sup> As illustrating some of the difficulties of the palæontology it may be noted that, of Sowerby's two types of *Ammonites plicomphalus* now preserved in the Natural History Museum, one is labelled as from 'Kelloway Rock, Bolingbroke,' and the other 'Kimeridge Clay.' Both are in a matrix of Spilsby Sandstone. In all the collections, fossils from the different horizons in Lincolnshire are much mixed.

<sup>2</sup> 'Argiles de Speeton,' p.116 (sep. copy).

<sup>3</sup> In collecting from the 'Pale Beds' (D 6) at Speeton I have obtained curious evidence of the former existence of large ammonites at this horizon. Full-grown *Exogyra (sinuata, var. cf. Couloni)* are of common occurrence, and one of these presented on one surface an excellent cast of a segment of the interior whorls and ribs of a large ammonite, to which the oyster had evidently been affixed. The cast is insufficient for specific determination, but shows clearly that the ammonite has not been of the deep-whorled *Polyptychites*-type such as tenant the overlying beds, but may have been akin to the *Craspedites*-group of *Olcostephani*.

few miles farther south, the Spilsby Sandstone is capped by this band of oolitic, clayey, and sometimes slightly gritty ironstone crowded with fossils, which is about 15 feet thick in the brow of the hill south of Nettleton, where it has been mined, but probably not elsewhere so thick. In this locality both the upward and the downward limits of the ironstone-rock are fairly definite, but it is usually overlain by a clayey band crowded with oolitic ferruginous grains which appears to contain the fauna of the ironstone along with a few newer forms. Northward it seems to thin out and disappear shortly before the accompanying strata are overlapped by the Upper Cretaceous rocks near Clixby. In the opposite direction it is still a well-marked feature in the series 12 miles south of Nettleton, the railway-cutting at Benniworth Haven, near Donnington, described by Mr. H. Keeping,<sup>1</sup> revealing 9 feet of this rock, while its original thickness may have been more than this; but farther south it appears to merge more or less into a clayey deposit. At the southern termination of the Wolds it is represented by irregular gritty ferruginous bands with deep partings of sandy clay. East of the Wolds it was recognized in the borings at Willoughby and Skegness, and in both localities was interstratified and mixed with clay.<sup>2</sup>

By Prof. Judd and the officers of the Geological Survey the Claxby Ironstone is classed with the Tealby Clay; but the earlier observers, Messrs. Dikes and Lee, were inclined to connect it with the underlying sandstone,<sup>3</sup> and Mr. H. Keeping observes that its fossils 'differ somewhat considerably from those of the clays and limestone above' (*op. cit.* p. 241).

As in the Spilsby Sandstone, lamellibranchs are the most abundant fossils. These are chiefly of the genera *Exogyra*, *Trigonia*, *Pecten* (including numerous individuals of the gigantic *P. cinctus*), *Cucullæa*, *Lima*, *Punopæa*, etc.<sup>4</sup> Many of the species occur likewise in the underlying sandstone. Brachiopoda are also numerous, especially in the Acre House section, where they seem to characterize the clayey material immediately overlying the harder rock (see section, p. 203).

The cephalopoda are represented by both ammonites and belemnites, but while the latter are of common occurrence, the former are rare and poorly preserved. All the belemnites that I have been able to observe in place in the Ironstone, whether at Nettleton Hill, Donnington, or Hundleby, have belonged to the *lateralis*-group (including *B. lateralis*, Phill., *B. russiensis*, d'Orb., and *B. sub-*

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 243.

<sup>2</sup> A. J. Jukes-Browne, *ibid.* vol. xlix. (1893) pp. 467 & 472.

<sup>3</sup> Messrs Dikes and Lee's description of the deposit is as follows:—'A mass of small, globular, shining grains, of a dark brown colour, cemented together by ferruginous matter; it occurs in the higher part of the bed [green sand and sandstone] nearly at its junction with the grey stone; and, possibly, ought to have been classed with it,' Mag. Nat. Hist. ser. 2, vol. i. (1837) p. 565.

<sup>4</sup> Prof. Pavlow (*op. cit.*) has recently recognized among these *Aucella Keyserlingi*, Lahus., a form well known in Russia.

*quadratus*, Roem.). But from the spoil-heaps of the abandoned mines near Acre House I have also obtained a few fragments of *B. jaculum*, along with two pieces of *Ammonites* (*Hoplites*) cf. *regalis* (*noricus* of Judd) and a fragment of *Olcostephanus*, near *Astierianus*, d'Orb., which appear to have been embedded in a matrix of clay with ironstone-grains.

The ammonites collected, with the above exception, are all deep-whorled *Olcostephani* (subgenus *Polyptychites* of Pavlow), including *Olcostephanus* (*Polyptychites*) *Blaki*, Pavl.; *O. (P.) Beani*, Pavl.; and *O. (P.) cf. ramulicosta*, Pavl.; which are all species characterizing the upper part of the 'Zone of *Belemnites lateralis*' at Speeton.

These cephalopoda alone are sufficient to fix the correlation with the Speeton section, and their evidence is confirmed by several other fossils common to the two areas; among others being *Exogyra sinuata*, var. (a well-marked form which I think should rank as a separate species), *Astarte senecta*, Bean MS., *Pholadomya*, sp., *Arca*, sp., etc. Many of the lamellibranchs, however, such as the *Trigonia*, *Cucullææ*, etc., and some of the brachiopods, which abound in the Claxby Ironstone and the Spilsby Sandstone, have not been found in the Speeton Clay, while other fossils, like certain species of *Lingula*, *Nucula*, etc. which are plentiful at Speeton do not occur in Lincolnshire. This differentiation of the contemporary faunas is evidently the outcome of the different conditions of depth, nature of sea-bottom, etc., prevalent in the two areas; and their mutually complementary character at these and other horizons will prove of the greatest value when the palæontology of the whole series comes to be exhaustively studied.

The Claxby Ironstone as developed at Acre House and Donnington may then be regarded as equivalent to the beds D 1 to D 4, forming the upper part of the 'Zone of *Belemnites lateralis*' in the Speeton section; and the presence of the precursors of a change of the fauna in its topmost clayey layer brings the stratum into the closest agreement with the Yorkshire beds, where we find the same indications at this horizon in the Compound-Nodule Band, D 1.

From this correlation it follows that the palæontological affinity of the deposit is altogether with the underlying Spilsby Sandstone, although stratigraphically it seems to be more closely connected with the overlying Tealby Clay. At Nettleton Hill it is clear that the ironstone and associated ferruginous clay extend quite to the top of the zone of *Belemnites lateralis*. That the striped clay immediately overlying it contains a different fauna is well shown by the following section, recently exposed by a slip in an old quarry, at the second fence south of the old mine-buildings near Acre House:—

*Section exposed by a slip in the quarried escarpment south of  
Acre House Mine.*

		Feet seen.
Tealby Clay.	Striped pale and dark blue clay, slightly loamy, with pale brown nodules with dark pyritous interior. <i>Belemnites jaculum</i> (rather plentiful), <i>Exogyra sinuata</i> (large typical form), and other (undetermined) shells ..... about	10
Claxby Iron- stone.	Clay crowded with oolitic ferruginous grains. <i>B. lateralis</i> (abundant); many brachiopods ..... about	1
	Slightly gritty oolitic ferruginous rubbly rock, crowded with fossils. <i>B. lateralis</i> , <i>Pecten cinctus</i> , <i>Exogyra sinuata</i> (small angular variety), etc. .... about	7
Spilsby Sandst.	Coarse greyish sand, indurated at the top, soft and incoherent below. <i>B. lateralis</i> , and casts of shells ... about	12

In the lower part of the Tealby Clay in this locality I have not been able to find any ammonites or other discriminative fossils except *Belemnites jaculum*, and am therefore unable to decide what portion of the extensive zone of *B. jaculum* is represented; but from the presence, at a slightly higher level, of forms which at Speeton make their first appearance 50 or 60 feet above the base of the zone, and from the absence of some characteristic species of the 'noricus-beds' (C 9, 10, & 11), I am inclined to think that not only in this section but throughout Lincolnshire the lower portion of the zone is absent, except for that small portion of it which may be represented by the clayey band forming the top of the Ironstone.

The unfortunate absence of sections prevents an accurate demarcation of the upward range of *Belemnites lateralis* farther south in Lincolnshire; though at Donnington, as at Nettleton, its limit must be at or about the top of the Ironstone, at which horizon H. Keeping<sup>1</sup> records *Amm. noricus* (*Hopl. regalis*). At any rate, the pit in Tealby Clay at the brickyard adjoining the railway-station there, which seems to be very little above the top of the Ironstone, yields no other belemnites except *jaculum*; while the ammonites, *Olcostephanus* (*Simbirskites*) *umbonatus*, Lahus., and cf. *Payeri*,<sup>2</sup> Toulia, and other fossils found in it show that the horizon is at least midway up in the Zone of *B. jaculum* (see p. 207). Nor, so far as the scanty evidence tells, is there anywhere south of this place any indication of *B. lateralis* in the clays above the Spilsby Sandstone until we reach the southern extremity of the escarpment, where just before the series disappears beneath the superficial deposits of the Fenland, we find an important modification of the conditions.

In this neighbourhood, from 1 to 2 miles west of Spilsby, there are outliers of clay on the Spilsby Sandstone, which at Hundleby, and again at Marden Hill near East Keal, have been extensively dug for brick-making. These clays have always been mapped and recognized as part of the Tealby Clay, and must indeed originally have been contemporaneous with that deposit; yet they contain *B. lateralis* and its accompanying fauna, from bottom to

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 242.

<sup>2</sup> See note, p. 207.

top as far as exposed, and must therefore be considered along with the Spilsby Sandstone and the Claxby Ironstone as forming, for palæontological purposes, the 'Zone of *Belemnites lateralis*.' The sections afforded by these pits are as follows:—

*Section at the western end of Hundleby Brickyard.*

	Feet.
Ferruginous gritty clay, partly indurated and nodular, with a few obscure fossils; rather like the Carstone in appearance.	3
Striped gritty clay .....	4
Band of irregular, round, brown, ferruginous nodules. <i>Ammonites</i> , cf. <i>gravesiformis</i> , etc.	
Striped pale- and dark-blue gritty clay .....	5
Band of large pale-brown nodules.	
Blue pyritous clay with pale sandy streaks, and flat pyritous nodules full of coarse grit. <i>Belemnites lateralis</i> ; small crushed ammonites; wood perforated by boring-shells, etc..	5

*Section at the south-western corner of Marden Hill  
(East Keal) Brickyard.*

	Feet.
Red clayey soil and drift, with fragments of chalk and flint.	
about	3
Weathered banded clay, brown, pyritous, and silty, with slightly ferruginous layers and sandy streaks, and a gritty seam at the base .....	4
about	
Silty blue clay with sandy streaks and ferruginous layers .....	5
Fossiliferous seam, with <i>Belemnites lateralis</i> , small crushed ammonites ( <i>Olcostephanus</i> ), and many small univalve and bivalve shells.	
Clay as above, rather more gritty, with coarse grit-grains in flat pyritous nodules. <i>B. lateralis</i> and other fossils as above, in places.....	17
Floor of lumpy ferruginous stone, like coalescent nodules, slightly gritty, and full of oolitic ferruginous grains. Many casts of fossils. <i>Ammonites</i> ( <i>Olcostephanus</i> ), cf. <i>gravesiformis</i> , etc., <i>Trigonia</i> , <i>Astarte</i> , etc.	

The fossils of these pits are practically identical. At Hundleby, though the unworked condition of the section at the time of my examination of it, in 1893 and again in 1895, was unfavourable for collecting fossils in place, I found fragments of *Belemnites lateralis* scattered in all parts of the pit, unmixed with any other form of the genus. I found also clay-stone casts of the deep umbilicus of 'coronated' ammonites akin to *Olcostephanus* (*Polyptychites*) *gravesiformis*, Pavl. (= *Ammonites Irius*, d'Orb., of Judd), exactly as they occur in bed D 3 at Speeton, together with some smaller specimens of the same group, *O. (P.)* cf. *Keyserlingi* and cf. *gravesiformis* (which are evidently the forms referred in the Geol. Surv. Mem. to *A. speetonensis*), and several brachiopods and lamellibranchs present in the Claxby Ironstone.

At Marden Hill on my last visit the section was quite fresh in one part of the pit, and here I obtained *Belemnites lateralis* in the clay within 9 feet of the top, and at lower levels down to the base of the pit, but found no trace of any other belemnite. Small

imperfectly-preserved ammonites, very similar to those which occur abundantly in the 'Astarte-bed' D 4 at Speeton, were rather plentiful at one horizon in the clay, and also in the ferruginous stone at the base of the pit, the species being the same as at Hundleby.

Most of the bivalves found in the other pit also occurred here; and in a silty band in the clay about halfway from the top of the section, along with some small crushed ammonites (*Olcostephani*), were numerous dwarf univalves and bivalves referable to *Dentalium*, *Cerithium* (?), *Pecten* (a Spilsby Sandstone form), *Isocardia* (?), *Astarte* cf. *senecta*, etc.

An important feature of both sections is the large admixture of coarse sand with the clay. This occurs throughout in little dabs and streaks, or in thin irregular seams tending to concentrate into shallow cakes of irregular outline, or to be caught up in the concretions of iron pyrites. In some places this sand is so coarse as to be almost pebbly, and the quartz-grains have a smooth polished surface, like the grains in the Spilsby Sandstone. Similar sandy clay associated with the Spilsby Sandstone seems to have been met with in the deep boring at Skegness, 11 miles farther east.<sup>1</sup> I have not found this gritty character in anything like the same degree in the Tealby Clay anywhere along its main outcrop under the Chalk escarpment.

From the Geol. Surv. Mem. ('East Lincolnshire,' pp. 14 and 22) we learn that the ferruginous stratum at the base of the Hundleby pit rests directly upon the Spilsby Sandstone, and that a well was sunk in it to a depth of 14 feet without reaching its base. The rock forming the floor of the Marden Hill pit is mentioned as being 'probably the same bed as that seen at Hundleby'; but it appears to me not unlikely that it may represent one of the higher nodular bands of the Hundleby section. The clay at Marden is rather more gritty, while at Hundleby there are bands of ferruginous concretions, in the clay above the base of the pit, which are not present at Marden, and the general field-evidence suggests that the Marden section is the higher.

In the Survey Memoir the Hundleby Ironstone is held to be the southern equivalent of the Claxby Ironstone, and the overlying clay is recognized as forming the base of the Tealby Clay. A list of the fossils of the clay is given (*op. cit.* p. 142), consisting of 13 species, with 9 further cases in which the genus only is determined. It is remarked at the foot of this list that 'this assemblage is also' (*i. e.* like that of the underlying Ironstone) 'eminently Neocomian.' *Belemnites lateralis*, *Ammonites speetonensis* and *A. Gowerianus* (?) are the cephalopoda mentioned, and these by no means establish the statement, while the remaining fossils, with the exception of one brachiopod, are all lamellibranchs of doubtful value as determinatives in this case.

At any rate, these sandy clays all fall within the zone of *B. lateralis*, and, as will presently be shown, their fauna is quite

<sup>1</sup> Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 169, ; see also Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 472.

distinct from that of the main mass of the Tealby Clay. And since we know that the Claxby Ironstone extends to the top of this *lateralis*-zone, it follows that the clays in question cannot represent a higher horizon than that deposit. These clays, with their accompanying bands of ironstone, occupy in fact the same position with regard to the Spilsby Sandstone at the southern end of the Wolds as the Claxby Ironstone farther north, and are equivalent in age.

We are thus brought face to face with an excellent example of that divergence of results which is bound to present itself sooner or later whenever the lithological and the palæontological characters of a stratified series are independently traced out over an extended area.

It cannot be denied that throughout Lincolnshire the Spilsby Sandstone and the Tealby Clay, and to some extent also the Claxby Ironstone, form well-defined stratigraphical units, which must be taken by the field geologist as the basis for his work in mapping out the structure of the country. Yet the palæontological evidence demonstrates that the boundaries of these continuous masses of like material are not strictly isochronous lines, but have had a progressive development.

It seems almost inevitable that in such cases the palæontologist and the stratigraphist must fix each his own limits independently of the other. The stratigraphist cannot well make use in the field of a line which forsakes a strongly-defined lithological junction to wander vaguely amidst a mass of uniform composition, wherein he could scarcely follow it even were there continuous sections in every direction. The palæontologist on the other hand is equally compelled to repudiate boundaries obliquely traversing time-limits and life-zones which he seeks above all things to define.

If we could study the extension of the whole series in an easterly direction, we should probably find this lateral change of lithological character even still more strongly marked. Apparently towards that quarter the various strata would merge into a clayey sequence such as we find at Speeton, as is indicated by the borings east of the Wolds. At Willoughby the full thickness of the Spilsby Sandstone was not proved, but the character of the stratum seems to have become greatly modified, being no longer a clean grit but an 'earthy sandstone' and 'ferruginous marlstone',<sup>1</sup> while in the Skegness boring already referred to, the Sandstone which is about 50 feet thick in the neighbourhood of Spilsby, has thinned away to 19 feet, and is associated with clay both above and below; and the overlying clays have thickened from about 70 to 191 feet. The presence at various horizons in the clay at Speeton of thin, imper-

<sup>1</sup> A. J. Jukes-Browne, Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 467. In this paper a somewhat different reading is given of the Skegness boring from that in the Geol. Surv. Mem. ('East Lincolnshire,' p. 168), and the thickness of the Spilsby Sandstone (including in this term some clayey material) is stated to be 26 feet. At a boring near Driby, if the record is to be trusted, only 4 feet of sand (Spilsby Sandstone) and 4 feet of ironstone (Claxby Ironstone?) was found between the Tealby Beds and the Kimeridge Clay (*ibid.* p. 155).



sistent ferruginous stone-bands,<sup>1</sup> probably indicates the final stages of this lateral change. Such changes are of course among the commonplaces of geology, and parallel examples might be adduced from beds of almost every age at home and abroad. Dr. J. W. Gregory has recently drawn attention to a striking example of similar conditions in the Gault and Lower Greensand of the South-east of England, and he, too, has pleaded the necessity for the recognition of two independent scales, the lithological and the chronological,—‘not contradictory, but complementary, and each must be retained for its special purpose.’<sup>2</sup>

### f. The Tealby Clay.

The available information regarding the exact age of the Tealby Clay along the major part of its course is very meagre, from the lack of clear exposures, and from the perishable character of the fossils which are largely pyritous.

Most of the sections have already been referred to, and will need very little further description. In the slope above the mine-buildings near Acre House the clays are exposed in a water-runnel and at a few other places in the same vicinity, including the slip-section already given (p. 203). The fossils noticed here are *Belemnites jaculum* in tolerable abundance, *Exogyra sinuata* (the large ‘Lower Greensand’ form, which is common in the beds C 4 and 5 at Speeton and differs from the allied shell occurring in the zone of *Belemnites lateralis*), *Nucula* sp. and several other small bivalves in a poor state of preservation, and some crustacean remains (*Meyeria* cf. *falcifera*, Phill.). In this locality the thickness of the Tealby Clay in the mine-shaft is stated at 40 feet.<sup>3</sup> In character it is a rather pale striped blue clay of fine texture, with a few small oval nodules of pale brown exterior and darker interior, which frequently contain fragments of crustaceans. This deposit, in its close lithological correspondence with its equivalent horizon at Speeton, stands alone among the members of the Lincolnshire succession.

Southward from Nettleton Hill I found no place, where the fauna of the clay could be studied, nearer than the pit at Donnington Station, mentioned on a previous page. The only other fossils which I have found here besides *Belemnites jaculum* (which is abundant) and *Olcostephanus* (*Simbirskites*) *umbonatus*, Lohs., are *Exogyra sinuata* (as above), *Pecten* sp., and other ill-preserved shells, *Serpula* sp., and *Meyeria* cf. *falcifera* (abundant). In the Geol. Surv. Mem., *Ammonites speetonensis* vars. *venustus* and *concinus*<sup>4</sup>, *Crioceras Duvalii*, and *Perna Mulleti* are also recorded from this place.

<sup>1</sup> See ‘Subdivisions of the Speeton Clay,’ Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 594, and sections, figs. 4 & 5.

<sup>2</sup> ‘On a Collection of Fossils from the Lower Greensand of Great Chart, in Kent,’ Geol. Mag. 1895, p. 103.

<sup>3</sup> J. W. Judd, Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 331.

<sup>4</sup> The specimens under this name are very near to, if not identical with, the form from my Speeton collection figured by Pavlow in ‘Argiles de Speeton,’ pl. xviii. (xi.) fig. 1, as *Olcostephanus* (*Simbirskites*) *Payeri*, Toulou, a species founded on specimens from the Island of Kuhn, off the coast of Greenland (see Toulou, ‘Geologie Ost-Grönlands,’ p. 498).

After this there is again a space of 8 miles in which, though the clay can be seen in places, no opportunity is afforded for obtaining fossils from it. Some old clay-pits about a mile to the eastward of Tetford are then reached, from the weathering slopes of which I have collected fragments of *Belemnites jaculum* in numbers, along with *Meyeria ornata*, Phill., *Exogyra sinuata* (as before), *Pecten* (probably *cinctus*), *Isocardia angulata*, Phill., and *Trochus pulcherrimus*? Fine selenite-crystals up to  $1\frac{1}{2}$  inch in diameter are also abundant. In general character the clay resembles that of Donnington and Acre House. The above-mentioned fossils are all Speeton species, and indicate that the horizon of this pit likewise is about midway in the 'Zone of *Belemnites jaculum*.' Yet the field-evidence shows that the pit cannot be far above the base of the Tealby Clay, which seems here to rest directly on the Spilsby Sandstone, the Claxby Ironstone apparently not being represented in this neighbourhood; and the absence of the lower part of the 'Zone of *Belemnites jaculum*' is thus once more indicated.

About  $1\frac{1}{2}$  mile farther south-east I found *Belemnites jaculum* washed out of the clay by a little stream running down the hill at South Ormsby; but in the remaining 6 miles between this locality and the southern termination of the Wolds at Spilsby no further fossil evidence was forthcoming. In the outliers to the westward of Spilsby, as has already been shown, the clays are of a different age and type.

So far therefore as the Tealby Clay under the Chalk escarpment can be examined, one stage only is represented, this being the middle and perhaps the upper portion of the 'Zone of *Belemnites jaculum*' (beds C2 or 3 to C5 or 6) of the Speeton Clay; while the rich fauna of the *Ammonites noricus (regalis)*-beds, which tenants 20 to 30 feet of clay in the lower part of this zone in Yorkshire, is not in Lincolnshire revealed in any visible section, except so far as its lowermost portion may be condensed in the uppermost clayey layer of the Claxby and Donnington Ironstone.

But the great expansion of these clays towards the east, which is a marked feature along the outcrop,<sup>1</sup> and is still better revealed in well-borings east of the Wolds at Alford, Willoughby, and Skegness, indicates that, as already hinted, the deposit almost certainly encroaches on both lower and higher zones in its prolongation in that direction, and gradually replaces, in part or wholly, the Spilsby Sandstone, the Claxby Ironstone, and the Tealby Limestone. Its greater thickness is therefore probably due, not so much to the thickening of the individual beds exposed at the outcrop, as to the incoming of higher and lower argillaceous deposits slightly different in lithological character and almost entirely different in fauna.

Under these conditions we may safely surmise that eastward, under the bed of the North Sea, the whole series merges into the

<sup>1</sup> A. Strahan, Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 488, and Geol. Surv. Mem. 1888, 'Country around Lincoln,' p. 96.

clayey sequence whose fringe is so conveniently revealed to us in the coast-section at Speeton. Westward and southward, on the other hand, it is very probable that the clays diminish, until the sands of the underlying and overlying horizons unite and become indistinguishable.<sup>1</sup>

### g. The Tealby Limestone (with the Upper Clay and 'Roach').

I have not devoted so much time in the field to the strata overlying the Tealby Clay as to those below that horizon, mainly because while their general correlation is readily arrived at, a more detailed comparison is rendered difficult by the still incomplete state of our information regarding the upper division of the Speeton Clay. Sufficient has been done, however, to demonstrate the relationship of these rocks to the rest of the section, and to improve our knowledge of their palæontology.

The hard calcareous bands with variable clay partings capping the Tealby Clay, known as the 'Greystone' or 'Tealby Limestone,' form a prominent feature in the stratigraphy between Caistor and Donnington, but are not definitely recognizable farther northward or southward, nor have any continuous hard beds been revealed at this horizon by the borings east of the Wolds. These facts, together with the thin and irregular character of the courses and the extent to which they are interbedded with, and in places overlain by, shaly or clayey material, suggest that the limestone is merely a locally calcareous modification of the upper portion of the Tealby Clay. It is therefore rather surprising to find how greatly the fauna differs from the known fauna of the Tealby Clay.

The limestone is best exposed in the numerous shallow pits between Normanby and North Willingham.<sup>2</sup> Fossils are everywhere present, but are not easy to extract; and there seems to be some difference in the species occurring in the different sections. The belemnites again supply the most definite information. They are frequently abundant, especially in the shaly partings, and are all recognizable as well-known Speeton forms occurring in the 'Zone of *Belemnites brunsvicensis*' (B), namely, *B. brunsvicensis*, Stromb., *B. speetonensis*, Pavl., and *B. Jasikowi*, Lahus. No other species have been found, and the record of *B. lateralis* from this horizon by Prof. Judd and the Geological Survey was evidently due to the confusion in the determination mentioned on a previous page.

Ammonites are rarer, the only serviceable specimens that I have myself discovered being found in the higher pit on the north side of the high road, east of North Willingham. These belong to the large

<sup>1</sup> For the discussion of this point see A. Strahan, 'On the Lincolnshire Car-stone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 491.

<sup>2</sup> In this locality the limestone-bands occasionally enfold phosphatic and pyritous concretions, just as the large limestone-nodules of the 'Compound-Nodule Band,' D1, of Speeton enclose similar earlier concretions.

clypeiform species usually recorded as *Ammonites clypeiformis*, d'Orb.,<sup>1</sup> examples of which under this name are preserved in most of our public collections of Lincolnshire fossils; but I do not think that this determination can be sustained. It is only in its adult stages that the ammonite assumes its sharply-keeled discoidal form and smooth sides, since the inner whorls present a rounded back and a few continuous ribs, the fossil at this stage being very near to, if not identical with, *Ammonites Carteroni*, d'Orb. It is possible that the young forms of this ammonite may occur at Speeton, but I have not seen an adult specimen there.

Among the other and more abundant fossils are *Pecten* (several species), *Exogyra sinuata* (the Tealby Clay form), *Ostrea frons*, Park. (plentiful here, but very rare at Speeton), *Lima*, *Pholadomya*, and many other lamellibranchs, with some brachiopods, etc. Several of the above occur at the equivalent horizon at Speeton, but their relative abundance in the two areas is very different.

*Pecten cinctus* is often very plentiful and of large dimensions, but I think that it displays characters of varietal, or even of specific value, differentiating it from the similar fossil of the Claxby Ironstone and Spilsby Sandstone. In the last-mentioned stratum the dwarfed representatives of the species can scarcely be distinguished from *P. lamellosus*, Sow., of the Portlandian, and when the fossil is studied throughout its extended range it will probably furnish the palæontologist with another illustration of a slowly-changing species, with all the usual difficulties, to which I suppose that he will in time become accustomed. Under present conditions the species is, as I pointed out in my former paper, of very little value as a zonal fossil.

The evidence of the fauna, then, suffices to enable us to recognize in the Tealby Limestone, as developed in the above-mentioned area, some portion of the 'Zone of *Bel. brunsvicensis*' (B) of the Speeton section; and the presence in Yorkshire in the clays of this horizon of a considerable amount of calcareous matter, which takes the form of bands of thickly-set septarian nodules of large size ('Cement Beds' of Judd), indicates that the deposition of more or less calcareous sediment was common to both districts at this stage.

The evidence is insufficient to demonstrate exactly how much of this extensive zone is represented by the Tealby Limestone, but it seems probable that if we could have complete sections we should find *Belemnites brunsvicensis* extending slightly below the base of the limestone in most localities, and also stretching upward at least as far as the lowest part of the Carstone.

Regarding the 'Roach Ironstone and Clay' which underlie the Carstone farther south, and are by the Geological Survey considered to be the southerly equivalents of the Tealby Limestone, I have no new information whatever to bring forward. Such scanty exposures of these deposits as I could find were unfossiliferous, and therefore practically useless for my purpose.

<sup>1</sup> J. W. Judd, Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 246; list reproduced in Geol. Surv. Mem. 1888, 'Country around Lincoln', p. 103.

### h. The Carstone.

The lithological characters and stratigraphical relations of the pebbly ferruginous sand which in Lincolnshire overlies the deposits above described, and extends upward to the Red Chalk, have been carefully set forth in the Survey Memoirs<sup>1</sup> and in Mr. A. Strahan's excellent paper on the subject in this Journal.<sup>2</sup> Except in the layer immediately below the Red Chalk, where *Belemnites minimus* and *Terebratula biplicata* are found, fossils are of very rare occurrence in it. Such as have been discovered are contained in eroded phosphatic nodules, and are supposed to have been derived from lower strata which have been destroyed.

The species recorded<sup>3</sup> are: *Ammonites speetonensis*?; *A. plicomphalus*? and *Lucina*? from a nodule-bed at its base near Otby; and *A. Deshayesii*, *A. triplex*, *Requienia*?, *Astarte*, *Corbula*, *Modiola*, *Myacites*, *Pholadomya*, *Cyprina*, and *Teredo*, from Claxby.

Not having myself succeeded in finding any of these fossils in the deposit, I have been unable to investigate their mode of occurrence and the character of the supposed 'pebbles' with which they are associated, and therefore am not in a position to discuss their origin. But from the nature of the list and the general features of the nodules in the stratum, I am inclined to consider their derivative nature not proven. At any rate, *Ammonites Deshayesii* is not far from its proper horizon, and, as already stated (p. 198), I am satisfied that where this species occurs in the Carstone at Hunstanton it is not derivative, but in place. The other ammonites mentioned, being all uncertain species, are of slight account in the discussion, while the remaining determinations of the list are too incomplete to afford any information.

As regards the stratigraphical relations of the deposit, I can corroborate Mr. Strahan's account of its upward passage into the Red Chalk, and the presence of *Belemnites minimus* in it just below the junction. In the southern part of its outcrop the Carstone has a thickness of about 40 feet, but northward it thins away, until in the last sections seen before reaching the Humber it remains only as a pebbly base to the Red Chalk. Both phenomena are exactly reproduced, as shown in an earlier part of this paper, by the ferruginous sands exposed in a few places along the western edge of the Yorkshire Wolds, which are no doubt the northern equivalents of the Carstone. And as it has been also shown that these Yorkshire sands can be correlated with much probability with the 'Passage-marls with *Belemnites minimus*' (A) of Speeton and Knapton (which, it may be noted, contain at the first-mentioned place 'lydites' and other small gritty particles), it follows that the same correlation must be

<sup>1</sup> 'Country around Lincoln,' pp. 105 *et seqq.*; 'East Lincolnshire,' pp. 23 *et seqq.*

<sup>2</sup> 'On the Lincolnshire Carstone,' Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 486.

<sup>3</sup> *Ibid.* p. 488; the Claxby list was supplied to Mr. Strahan by Mr. H. Keeping.

applied to the Lincolnshire Carstone. But if *Hoplites Deshayesii* be in place in Lincolnshire as in Norfolk, it would appear that where the Carstone is fully developed its lower portion must lie within the 'Zone of *Belemnites brunsvicensis*,' in which event the interval between it and the Tealby Limestone cannot be great.

Indeed under any circumstances, if I am right in thinking that no break exists at Speeton between the 'Passage-marls' and the clays containing *B. brunsvicensis*, *Hoplites Deshayesii*, and *Amaltheus bicurvatus*, any unconformability which may exist at the base of the Carstone, as supposed by Mr. Strahan, must possess a relatively small time-value where that deposit overlies the Tealby Limestone Series, since on comparison of this part of the Lincolnshire sequence with that of Speeton there is seen to be little or nothing lacking.

At the upper boundary of the deposit it is very probable that there may be in some degree a lateral as well as a vertical passage into the Red Chalk. That the accumulation of sand in the shallower or more exposed areas probably continued for some little time after the deposition of the chalky sediment had commenced in adjacent regions is, I think, directly suggested by the evidence made known to us by Mr. W. Hill in his careful study of the lower beds of the Upper Cretaceous rocks.<sup>1</sup> With the Red Chalk commenced that period of slow depression, which in its later stages brought back once more an uniformity of conditions over the eastern part of England which had not existed since Kimeridgian times. This depression swept away the more local influences which had hitherto prevailed in South Yorkshire and North Lincolnshire, where a belt of country had been slowly brought up within reach of the denuding agencies and gradually planed down. South and east of the elevated area, even where the marine conditions were continuous, the proximity of land and the gradual change in its outline affected from time to time the factors which govern the accumulation of sediments, so that in Mid-Lincolnshire the deposits of this period are marked by their local and changeful characters.

#### V. STATEMENT OF THE CORRELATION.

The result of this investigation is to show that in Lincolnshire, as in Yorkshire, the various species of belemnites present in the rocks afford the most natural and convenient means for classifying the strata; but that the well-defined zones which they form do not always coincide with the lithological divisions.

Of these zones, that of *Belemnites lateralis* appears to be quite as fully represented in Lincolnshire as at Speeton. The 'Zone of *Belemnites jaculum*,' which occupies so large a proportion of the Speeton Clay, is in most of the Lincolnshire sections condensed into narrow limits, and may be in part unrepresented.

The 'Zone of *Belemnites brunsvicensis*' is well exhibited, but from the unfossiliferous character of some of the sediments and the lack of

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 320.

IN YORKSHIRE AND LINCOLNSHIRE.

EETON LIFF.	South- ward. →	Nettleton Hill, Lincolnshire.		Southern part of Lincolnshire Wolds.
CHALK		RED CHALK		RED CHALK
CARLS with minimus		CARSTONE		CARSTONE
E CLAYS with careous nodules		TEALBY LIMESTONE		? Upper Clay and "Roach" Ironstone
STRIPED CLAYS nodular uginous ands		TEALBY CLAY		TEALBY CLAY
BRITOUS CLAYS nodular ands		CLAXBY IRONSTONE		TEALBY CLAY of Hundleby and "HUNDLEBY" IRONSTONE
OLITE-BED		SPILSBY SANDSTONE		SPILSBY SANDSTONE
KIMERIDGE CLAY		KIMERIDGE CLAY		KIMERIDGE CLAY





DIAGRAM SHOWING THE CORRELATION OF THE SPEETON SERIES IN YORKSHIRE AND LINCOLNSHIRE.

Fossil Zones.	Western edge of Yorkshire Wolds.	Knapton, Yorkshire.	West-ward.	SPEETON CLIFF.	South-ward.	Nettleton Hill, Lincolnshire.	Southern part of Lincolnshire Wolds.
A. Zone of <i>Bel. minimus</i> , <i>List.</i>	RED CHALK FERRUGINOUS SANDS and pebble-beds.	RED CHALK MARLS with <i>Bel. minimus</i>		RED CHALK MARLS with <i>Bel. minimus</i>		RED CHALK CARSTONE.	RED CHALK CARSTONE.
B. Zone of <i>Bel. brunsvicensis</i> , <i>Stromb.</i>	WANTING	CLAYS with <i>Amm. Deshayesi</i>		BLUE CLAYS with Calcareous nodules		TEALBY LIMESTONE	? Upper Clay and Roach Ironstone
C. Zone of <i>Bel. jaculum</i> , <i>Phill.</i>	WANTING	?		STRIPED CLAYS with nodular ferruginous bands		TEALBY CLAY	TEALBY CLAY
D. Zone of <i>Bel. lateralis</i> , <i>Phill.</i>	WANTING	WANTING ?		PYRITOUS CLAYS with nodular bands		CLAXBY IRONSTONE SPILSBY SANDSTONE	TEALBY CLAY or Hundleby and Hundleby IRONSTONE SPILSBY SANDSTONE
E.	WANTING	WANTING ?		COPROLITE BED		PHOSPHATIC NODULE BED	PHOSPHATIC NODULE BED
F. Shales with <i>Bel. Owenii</i> , etc.	(USUALLY) WANTING	KIMERIDGE CLAY		KIMERIDGE CLAY		KIMERIDGE CLAY	KIMERIDGE CLAY

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clear sections, only the broader features of its relationship can be demonstrated.

In both areas the uppermost beds of the series pass upward into the Red Chalk.

The correlation of the typical sections of each district is illustrated in the diagram facing the opposite page.

## VI. THE AGE OF THE *BELEMNITES LATERALIS* BEDS.

The definite purpose of my paper was to bring out anew, and to place on a more satisfactory basis, the relationship of the strata underlying the Chalk in Yorkshire and Lincolnshire, and I venture to hope that in the preceding pages this has been accomplished. As for the broader issues to which this work gives rise, I think they may for the most part await with advantage the accumulation of fuller and more accurate information on many points. In England there is still much to be done, both in the study of the palæontological material already collected, and in the re-examination, in the light of the new evidence, of the region lying to the southward of that herein discussed. In the Eastern Midlands at least some portion of the fauna of the Speeton Series (including *Belemnites (lateralis) subquadratus*) is preserved in some of the phosphatic-nodule beds, but whether in an original or derivative form is still uncertain. In several regions abroad also, and especially in Germany, the information which we possess regarding the corresponding strata is at present conflicting and insufficient, and will undoubtedly be considerably affected by researches which are now in progress. I had indeed hoped that my esteemed friend Prof. Pavlow would have been able to lay before the Society on this occasion a *résumé* of the available facts respecting the Continental equivalents of the series. But Prof. Pavlow has at the last moment, from physical indisposition, found it impossible to complete his notes in time. We may hope, however, that he will shortly be able to bring forward his valuable contribution on the subject.<sup>1</sup> Meanwhile I think that a brief recapitulation of the work already published, bearing on the disputed question of the age of the Zone of *Belemnites lateralis*, will form a fitting conclusion to this paper.

Leckenby seems to have been the first definitely to formulate the view that the lowest part of the Speeton Clay should be classed as Jurassic, basing his opinion mainly on the occurrence therein of coronated ammonites of the *Gravesianus*-type.<sup>2</sup> These ammonites were afterwards supposed by Prof. Judd to have been obtained from beds capping the Upper Kimeridge shale, but below the clays with *Belemnites lateralis*.<sup>3</sup> In my former paper, however, I was

<sup>1</sup> [While this paper was passing through the press, the communication of Prof. Pavlow above referred to, 'On the Classification of the Strata between the Kimeridgian and Aptian,' was read, and its publication may be looked for in a subsequent number of the Journal.—April 22nd, 1896.]

<sup>2</sup> See note by J. Leckenby in Dr. T. Wright's Monogr. 'Brit. Cret. Echinod.,' Pal. Soc. vol. xxi. pt. i. p. 9.

<sup>3</sup> 'On the Speeton Clay,' Quart. Journ. Geol. Soc. vol. xxiv. (1868) p. 218.

able to prove that the true horizon of these fossils was the upper part of the Zone of *Belemnites lateralis*. Hence, if these ammonites were sufficient to demonstrate the Portlandian age of the rocks containing them, the line between Jurassic and Cretaceous in the Speeton section must, I urged, be drawn at the top of this zone, as Leckenby proposed, and not at its base, as Prof. Judd had suggested.

Meanwhile the subject had been attacked from an entirely different standpoint by the Russian geologists M. Serge Nikitin (of the Russian Geological Survey) and Prof. A. Pavlow (Moscow University), who had attended the meeting of the International Geological Congress in London in 1888, and had taken the opportunity then afforded of studying the Speeton section and its fauna upon the spot. These gentlemen soon afterwards published independent readings of the section and its correlation,<sup>1</sup> differing in some important points, but agreeing in recognizing in the Zone of *Belemnites lateralis* the equivalent of the 'Upper Volga Beds' of Central Russia and the Purbeck of the South of England. Nikitin however considered that the ammonites afforded no evidence of the Jurassic age of the beds, since they had been incorrectly determined, and belonged in reality to species recognized as Neocomian in Germany.<sup>2</sup> He was thereby confirmed in his previously-expressed opinion that the Upper and Lower Volga Beds of Russia (and presumably also their English equivalents) should be regarded neither as Jurassic nor Cretaceous, but strictly as passage-beds between these systems. Pavlow, on the other hand, thought that a stricter definition was possible, especially as he regarded the Zone of *Belemnites lateralis* as equivalent not only to the Purbeck, but also to the Portland Stone of the South of England.

In a later memoir<sup>3</sup> (to which I had the honour of contributing a chapter respecting the stratigraphy of the deposits in the North of England) Prof. Pavlow, continuing to work on the same general lines, extends his study of the subject to embrace the whole of the North European area, and shows that the cephalopoda of these rocks confirm in most points his former conclusions. He finds a certain amount of difference between the fauna of the upper and the lower portions of the Zone of *Belemnites lateralis*, which enables him to divide it into two parts characterized by different types of ammonites (in the same manner as the Zone of *B. jaculum* is

<sup>1</sup> S. Nikitin, 'Quelques Excursions dans les Musées et dans les Terrains Mésozoïques de l'Europe occidentale,' Bull. Soc. Belge de Géologie, vol. iii. Mém. pp. 29-58 (1889); A. Pavlow, 'Études sur le Jurassique supérieur et le Crétacé inférieur,' Bull. Soc. Imp. Naturalistes de Moscou, n. s. vol. iii. (1889) p. 61.

<sup>2</sup> The German evidence becomes here of extreme importance, and I am very glad to learn that the whole question is now being carefully re-studied in that country. If the German equivalent of the zone of *Belemnites lateralis* has been considered Neocomian only on the strength of the old Speeton correlation, no argument could be safely deduced from this quarter. But from its geographical position the succession in Germany will probably eventually be found comparable with several surrounding areas, and thus the linking together of the outlying regions will be more securely done than is at present possible.

<sup>3</sup> 'Argiles de Speeton,' Moscow, 1891-1892.

divided), the lower being tenanted by *Olcostephanus* (*Craspedites*) *subditus* and allies, and the upper by *O. (Polyptychites) gravesiformis* and allies. These together form the 'série Speetono-russe' (p. 174), which he shows to be equivalent to the Upper Portlandian (Purbeck and Portland Stone) of the South of England, and he proposed to designate these rocks the 'sous-étage Aquilonien' (p. 192). He then discusses exhaustively the correlation of this 'Aquilonian sub-stage' throughout Europe, and shows that everywhere in Southern as well as in Northern Europe the equivalents of this sub-stage underlie the 'étage Néocomien inférieur,' which upon various considerations is declared the true base of the Lower Cretaceous system. He further urges in favour of this grouping that it agrees best with the older definitions and traditions of the science, and concludes his argument thus:—'Si nous replaçons l'ancienne limite entre les deux systèmes nous nous privons d'une limite très nette, paléontologiquement très bien définie, et qui, grâce à la transgression remarquable de la faune méridionale vers le Nord, peut-être observée dans une vaste région, circonstance qui nous fait considérer cette limite comme très heureusement choisie par les coryphées de la science et comme très précieuse au point de vue de la stratigraphie comparée. Cette limite a été tracée par la nature même comme une limite ayant fixé l'époque d'un événement géologique remarquable, savoir la disparition d'une partie considérable du continent portlandien et le commencement de la migration de la faune méridionale vers le Nord, et réciproquement peut-être.' ('Argiles de Speeton,' sep. cop. p. 199.)

But to establish this classification it became necessary to carry down into the Jurassic system not only the whole of the Berriasien of South-eastern France, but also the so-called Wealden and the Hills Conglomerate of North-western Germany, and in doing this Pavlow is at variance with the opinions of several geologists of the Continent, so that the subject must be considered as still under discussion. Indeed, in a later paper, 'On the Mesozoic Rocks of the province of Riasan, Russia' (Moscow, 1894),<sup>1</sup> if I rightly understand the brief final *résumé* in French, Prof. Pavlow seems inclined to grant that recent discoveries have shown that the 'Petchorian sub-stage,' capping the 'Aquilonian,' with *Olcostephanus stenomphalus* in the lower part and *Polyptychites Keyserlingi* in the upper portion, may in that region correspond to the Lower Neocomian of Central Europe. In his forthcoming notes on the subject Prof. Pavlow will no doubt discuss this new evidence, and show its exact bearing on the question at issue.

So far as the classification of the English strata is concerned, it must, I think, be admitted that the limit of the Lower Cretaceous and Jurassic systems is more or less arbitrary and conventional, often without reality in the field, and is therefore to be treated on a basis of general convenience and historical priority.<sup>2</sup> And this

<sup>1</sup> Scient. Mem. (Ucheniya Zapiski) Imp. Univers. Moscow, vol. xi. p. 1.

<sup>2</sup> See H. B. Woodward, Geol. Surv. Mem. 'Jurassic Rocks of Britain,' vol. v. p. 3.

state of affairs prevails, as the above discussion has indicated, not in England only, but throughout the greater part of Europe, and also in North America. Under such conditions there must necessarily be much discussion and interchange of views before a boundary of general application can be agreed upon. Nor is this at all attainable except by some sacrifice in matters of local convenience.

Thus, in the North of England there is no doubt that in spite of the early-recognized and oft-discussed Jurassic affinities of the Spilsby Sandstone fauna,<sup>1</sup> the field-geologist working independently in that district would find the base of that deposit to afford by far the most suitable line of demarcation between the systems. It is a strongly-defined horizon, marking the termination of a period of quiet and uniform sedimentation over the whole region, while above it, owing to more local and less stable conditions, the character of the accumulation frequently alters horizontally as well as vertically, thereby rendering the tracing-out of a synchronal line a matter of extreme difficulty. Yet it seems inevitable that, in spite of its convenience, this line will have to be abandoned whenever the wider bearings of the stratigraphy of the region are in question, unless we are prepared to advocate extensive alterations in other areas to suit it. If, on the other hand, we take the upper boundary of the *lateralis*-zone as our line of division, we find that though in Yorkshire, as Leckenby pointed out, this horizon is lithologically well defined, in Lincolnshire, as already shown, in the southern part of its course it is purely palæontological and scarcely traceable on the ground.

The division of the Zone of *Belemnites lateralis* into two portions by means of the ammonites, as proposed by Pavlow, suggests the possibility of an alternative course, by which the lower part with *Ammonites subditus*, corresponding to the major portion of the Spilsby Sandstone and presumably to Beds D 5 to D 8 of Speeton, might be separated from the rest of the zone, in which occur the '*gravesiform*' ammonites, and the one classed as Jurassic and the other as Cretaceous. [This scheme is powerfully advocated by Prof. Pavlow in his recent contribution to the Society.] But while this plan would possibly satisfy some of the objections which have been raised to the inclusion of the whole zone in the Jurassic, it appears to me that the life-forms other than the cephalopoda common to the two parts of the zone will, when fully worked out, be found so numerous that a line drawn at this horizon would in England be both palæontologically and stratigraphically weak, without serving the general European convenience better than before.

<sup>1</sup> Prof. H. G. Seeley, in the discussion on J. F. Blake's 'Portland Rocks of England,' Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 236, and in several earlier discussions on similar subjects.

Mr. G. Sharman, in Geol. Surv. Mem. 1887, 'East Lincolnshire,' p. 141, in discussing the fossils, remarks:—'It is tolerably evident, therefore, that these calcareous concretions (of the Spilsby Sandstone) occupy a lower horizon than any Neocomian beds hitherto described, and, in so far as palæontological evidence goes, seem to occupy an intermediate position between the lowest Neocomian and the uppermost Oolites.'

However, where so much uncertainty still exists, it appears to me that, pending the accumulation of further evidence, we shall scarcely be justified in pronouncing on one side or the other a final decision in this matter. Even with regard to the rocks of this age in the South of England, on the classification of which the whole of this discussion hinges, there is still much obscurity. It seems now to be very generally acknowledged that there is a passage from Purbeck to Wealden where both are fully developed<sup>1</sup>; and recently even the strength of the evidence on which the Wealden itself is classed as Cretaceous has been challenged, and the chief elements of its fauna declared by several authorities to be Jurassic rather than Cretaceous in their affinities.<sup>2</sup>

It appears, in short, to be the fact that while over Western Europe there is usually a distinct stratigraphical break at the base of the Upper Cretaceous, as Mr. Strahan and others have frequently pointed out,<sup>3</sup> the base of the Lower Cretaceous, as at present recognized, whether the sequence be freshwater or marine, presents no such break, but a more or less gradual passage both in character of deposit and in fauna. Under such conditions it is mainly a question of general convenience what particular horizon shall be taken as the boundary of the systems, and the essential determinative must rest in the agreement of competent opinion.

## VII. CONCLUDING SUMMARY.

The leading conclusions of this paper may be epitomized as follows:—

1. Further work on the Speeton section, while extending our knowledge of the palæontological details, has fully sustained the results of the author's previous investigations.
2. The evidence at present available is insufficient to demonstrate the exact conditions which bring about the rapid attenuation and final disappearance of the Speeton Series in a westerly direction in Yorkshire. Contrary to the accepted view, however, the lower zones are probably the first to die out, and are overstepped or overlapped westward by the higher divisions, since at Knapton, 14 miles inland, only the upper zones of the coast-section can be proved to occur, as shown by the presence of the marls with *Belemnites minimus* passing upward into the Red Chalk, and by the fossils in the old collections, including *Hoplites Deshayesii*, under the name of *Ammonites knaptonensis*, Bean MS., and a few others of the same zone.

<sup>1</sup> See H. B. Woodward in Mem. Geol. Surv. 'Jurassic Rocks of Britain,' vol. v. pp. 3 and 243 *et seqq.* (with good bibliography).

<sup>2</sup> O. C. Marsh, Geol. Mag. 1896, p. 8; [also in 'Nature,' vol. liii. (1896), p. 436, as regards the reptiles; A. S. Woodward, Geol. Mag. 1896, p. 70, as regards the fishes; and A. C. Seward, in 'Nature,' vol. liii. (1896) p. 462, as regards the plants].

<sup>3</sup> See, among others, A. Strahan's recent paper 'On Overthrusts of Tertiary date in Dorset,' Quart. Journ. Geol. Soc. vol. li. (1895) p. 561.

3. The ferruginous sands which occur locally beneath the Red Chalk on the western edge of the Yorkshire Wolds are recognized as agreeing in all respects with the Lincolnshire Carstone, and where absent are to some extent represented by a pebbly base to the Red Chalk, as in Lincolnshire. In both counties Mr. A. Strahan's conclusions as to the relations of the Carstone to the Red Chalk are confirmed.
4. In Mid-Lincolnshire all the palæontological zones of the Speeton Series are identified and traced; and though their lithological aspect is greatly modified, and is accompanied by a corresponding modification of their fauna, the presence of the leading zonal types of the cephalopoda readily establishes the general correlation proposed by Prof. Pavlow and the author, which differs in many respects from that adopted by previous investigators.
5. In Lincolnshire, in at least one instance, the synchronal boundary, as indicated by the limits of a palæontological zone, is shown not to pursue the same stratigraphical horizon throughout its course, proving that sediments of different character were accumulated simultaneously in comparative proximity to each other. The inherent divergence between the stratigraphical and palæontological methods in geology is thus once more illustrated.
6. The derivative character of the band of phosphatic nodules at the base of the Spilsby Sandstone is stated to be very doubtful; and the fossils of these so-called 'pebbles,' as of the corresponding horizon at Speeton, are considered as probably representing an original fauna, poorly preserved in nodules formed during a temporary pause in the sedimentation.
7. It is shown that the 'Zone of *Belemnites lateralis*' bridges over the space between undoubtedly Jurassic and undoubtedly Lower Cretaceous strata; but if the accepted classification of other areas is to be upheld, it appears to be necessary that the division between the systems should be placed high enough to include this zone, or at least the greater part of it, in the Jurassic, in spite of the local inconvenience of this arrangement.

#### DISCUSSION.

The PRESIDENT said that it was hardly possible, when mapping in the field, to do more than follow those petrological changes in the character of beds over any given area which are patent to the observer. The point discussed by the Author is that the life-line does not follow the line of the same sedimentation, but life-forms may transgress, and do transgress, over sediments of different character when they happen to be accumulated at the same time. It is hoped, however, that the case propounded by the Author is exceptional, and that, as a rule, the sediments and the fossils follow one another on the same lines.

Prof. JUDD congratulated the Society upon the valuable details now communicated by the Author, and on the important work on



the fossils which had been done by him and Prof. Pavlow. He thought that the admissions of the Author, however, pointed to the desirability of the use of ammonite-zones in preference to those based on belemnites. He also demurred to the excessive importance attached to minute points of palæontological evidence when seeming to be in conflict with the stratigraphical evidence.

Mr. STRAHAN was prepared to find the palæontological and stratigraphical grouping of these rocks slightly at variance. He had pointed out some years ago that the Spilsby Sandstone became finer in grain and was partly replaced by clay eastwards. Northwards, towards Speeton, the same change took place, and no doubt the Author was correct in attributing a portion of the clay at Hundleby to that subdivision—on palæontological grounds. At the same time, it was inexpedient to draw any other line on the map than that which had been taken. The separation of Jurassic from Neocomian in Lincolnshire was based on stratigraphical considerations. A glance at the map showed that the Neocomian group followed the Upper Cretaceous through much of its range across Lincolnshire and Yorkshire; and though the great overlap took place at the base of the Upper Cretaceous, yet there was also an unconformity at the base of the Neocomian. So far as the North-east of England was concerned, no other division between Jurassic and Neocomian than that adopted by the Geological Survey was possible; had a local name been used in preference to the imported term 'Neocomian,' much confusion would have been avoided.

He had always regarded the nodule-bed in the Spilsby Sandstone as a true conglomerate—a natural accompaniment of the unconformity referred to. The nodules are clustered in a thin band at the base of the rock; they differ in their mineralization from the indigenous fauna; the recognizable forms resemble Kimeridge Clay as much as they do Neocomian forms; the nodules show every degree of wear and tear, and are rounded as though by rolling, and not pitted as they would be by corrosion, nor have they attached to them any of the original shell, nor any adherent organisms. He did not argue that they had been derived from beds now underlying the Spilsby Sandstone, but from strata that had been washed away. The same arguments were applicable to the nodules in the Carstone, which could be readily distinguished into indigenous and derived.

He thought it a matter for congratulation that they had had laid before them another of the Author's valuable contributions on this interesting group of rocks, and trusted that Mr. Lamplugh would eventually extend his observations to the South Coast.

Mr. H. B. WOODWARD remarked that, while in Dorset there was a passage from Kimeridge Clay into Portland Beds, in Lincolnshire the Spilsby Sandstone near Spilsby rested on Upper Kimeridge Clay and north of Caistor it rested on Lower Kimeridge Clay, so that there was a break between the nodule-bed and underlying clays. He said that it should be borne in mind that a similar nodule-bed, also containing derived Portlandian fossils, occurred at the base of the Woburn Sands at Brickhill, there resting on the Oxford Clay.

Mr. R. S. HERRIES congratulated Mr. Lamplugh on his paper and said that from his knowledge of the Author's excellent work at Speeton he felt every confidence in the correctness of his interpretation of the Lincolnshire sections. He was especially interested in that part of the paper which dealt with the boundary between the Neocomian and Jurassic, as in this he saw the elements of a reconciliation between the diverse views of Prof. Judd and the Author. He wished to say how much assistance he had derived from Prof. Judd's paper while working on the Speeton section.

Mr. G. C. CRICK desired to bear testimony to the value of the paper. So far as the beds in question were concerned, he agreed with the Author in using the belemnites to characterize the various zones. He mentioned that much of the confusion which had arisen with respect to the determination of some ammonites, such as *Ammonites biplex*, was due to the unsatisfactory conditions of the types, some of these having been obtained from the Drift.

Mr. W. H. HUDLESTON also spoke.

The AUTHOR was glad to learn that Prof. Judd was inclined in the main to accept his results. As for the belemnites, their peculiar value as zonal fossils in the area described was, not only that they were abundant, but that owing to the intervention of the southern forms of the *jaculum*-group between the *lateralis*- and the *brunsvicensis*-groups of the northern *explanati*, the boundaries were very definite and easy to trace. He was quite ready to grant to Mr. Strahan and Mr. Woodward that an unconformity might exist at the base of the Spilsby Sandstone, and even that true pebbles might exist at this horizon, though he had himself failed to find any. His contention was, however, that the phosphatized casts of fossils were not derivative as had been supposed, but represented a fauna proper to the horizon and to some extent distinct from that of the overlying portion of the Sandstone. The condition of the casts appeared to be similar to that of the nodules dredged up by the *Challenger* expedition. He allowed that such nodules might form pebbles upon the destruction of their original matrix, but held that this explanation should be adopted only when the evidence was convincing, and not in such cases as this, where (as he had tried to show) it was insufficient. He thanked the Society for the kindly reception accorded to his paper.

9. *On some PODOPHTHALMATOUS CRUSTACEA from the CRETACEOUS FORMATION of VANCOUVER and QUEEN CHARLOTTE ISLANDS.*  
By HENRY WOODWARD, LL.D., F.R.S., F.G.S. (Read January 22nd, 1896.)

SOME time since I received from my friend Mr. J. F. Whiteaves, F.G.S., Palæontologist to the Geological Survey of Canada, several interesting crustaceans from the Cretaceous coal-bearing formation of Vancouver and Queen Charlotte Islands, and, as they offer a close affinity with forms from our own Gault and Greensand, they are deserving of special notice.

The existence of Cretaceous strata in Canada has long been known, and the coal-fields of Nanaimo and Comox on Vancouver Island have been correlated with this formation as well as those of Queen Charlotte Island and Alberta, eastward of the Rocky Mountains.

Mr. F. B. Meek in 1857 gave a description of new organic remains from the Cretaceous of Vancouver Island, including *Baculites ovatus*? Say; *Ammonites* (*Scaphites*) *ramosus*, *A. Newberryanus*, *Dentalium nanaimoensis*, *Thracia* (?) *occidentalis*, *Thr.* (?) *subtruncata*, *Trigonia Evansana*, *Pholadomya subelongata*, *Ph. (Goniomya) borealis*, *Cardium scitulum*, *Arca vancouverensis*, *A. (Cucullæa) æquilateralis*, and *Nucula Traskana*. Dr. B. F. Shumard in 1858 added *Inoceramus vancouverensis*, *Pinna calamitoides*, and *Pyrula glabra* to the Nanaimo fauna.

In Prof. H. Y. Hind's 'Report on the Assiniboine and Saskatchewan Expedition' (1859) further lists of fossils are given, 13 in number, all referred to Cretaceous forms, namely:—

*Anomia Flemingii*.  
*Inoceramus canadensis*.  
*Avicula linguiformis*, E. & S.  
— *nebrascana*, E. & S.  
*Leda Evansi*, Hall & Meek.  
*Rostellaria americana*, E. & S.  
*Natica obliquata*, Hall & Meek.

*Leda Hindi*, Meek.  
*Avellana concinna*, H. & M.  
*Ammonites placenta*, Dekay.  
*Scaphites nodosus*, Owen, var.  
— *Conradi*, Morton.  
*Nautilus Dekayi*, Morton.

In 1861 Dr. (now Sir) James Hector instituted a comparison between the strata east of the Rocky Mountains with those of Vancouver Island (Capt. Palliser's Exploring Expedition, 1857–60).<sup>1</sup> The list of Cretaceous fossils contributed by Mr. Etheridge from east of the Rocky Mountains comprised:—

*Ostrea anomiaformis*.  
— *lugubris*, Conrad.  
— *cortex*, Conrad.  
— *vellicata*, Conrad.

\* *Inoceramus Crippsii*, Roemer & C.  
*Leda Hindi*, Meek.

*Astarte texana*, Conrad.  
*Cardium multistriatum*, Shumard.  
*Cytherea texana*, Conrad.  
*Pholadomya occidentalis*, Morton.  
*Baculites compressus*, Say.

\* *Inoceramus Crippsii* (Roemer) and *Baculites compressus* (Say) are stated to be common to the Cretaceous rocks of the plains and of Vancouver Island; while of the whole 18 species not less than 13 are identified with Texan or Mexican species.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xvii. (1861) pp. 388–445.

Those from Nanaimo, Comox, or Valdez Inlet are :—

*Inoceramus texanus*, Conrad.  
 — *nebrascensis*, Owen.  
 — *undulatoplicatus*, Roemer.  
 — *confertim annulatus*, Roemer.

*Inoceramus mytiloides*, Conrad.  
*Trigonia Emoryi*, Conrad.  
*Cytherea leonensis*, Conrad.  
*Ammonites geniculatus*, Conrad.

In 1861 Mr. Meek (Proc. Acad. Nat. Sci. Philad. vol. xiii. p. 314) added to the list of Cretaceous fossils from Vancouver *Dosinia tenuis*, from Nanaimo; *Inoceramus subundatus*, *Baculites occidentalis*, *Ammonites vancouverensis*, and *Nautilus Campbells*, from Comox; *Ammonites complexus*, var. *suciensis*, from Comox and the Sucia Islands; and *Baculites inornatus*, from the Sucia Islands.

In 1864 Mr. W. Gabb, in vol. i. of the 'Palæontology of California,' described and figured two new species of fossil shells, namely:—*Hamites vancouverensis* and *Pecten Traskii* from Nanaimo.

For an admirable summary of our knowledge of 'the Cretaceous System of Canada,' see the Presidential Address to the Royal Society of Canada by J. F. Whiteaves, Section iv., May 23rd, 1893, pp. 3-19 (Trans. Roy. Soc. Canada).

I find that it is impossible here to give a full list of all the fossils obtained from these beds, and I have omitted the fossils of the upper series of deposits entirely, as also the plant-remains.

Besides the mollusca, a decapod crustacean (named but not described as *Hoploparia* or *Podocrastes*? *dulmenensis*) has been recorded from the Niobrara-Benton group of Manitoba—a long-tailed decapod (*Palæastacus*) from the Pierre Fox Hills or Montana formation, and a beetle, *Hyllobites cretaceus*, Scudder, from the Pierre Shales, Millwood, Manitoba.

The species of crustacea now to be noticed comprise :—

1. Several examples of a small macrurous decapod belonging to the genus *Callianassa*, met with very frequently in the Faxoe Beds, the Maestricht Chalk, the Greensand of Colin Glen, Belfast;<sup>1</sup> and also from lower beds (*C. isochela*),<sup>2</sup> Kimeridge Clay of the Sub-wealden boring; and from higher and later ones, namely, *Callianassa Batei*,<sup>3</sup> Upper Marine Series, Hempstead, Isle of Wight.

This is a small burrowing crustacean, and is found living at the present day; usually only the chelæ are obtained in dredging, owing to the animal lying in its burrow, and the hands alone protruding from the aperture.

The body- (thoracio-abdominal) segments are nearly soft, owing to the animal's constant habit of lying concealed, only the hands having a hardened calcareous covering.

<sup>1</sup> *Callianassa neocomiensis*, H. Woodw. Brit. Assoc. Rep. (Norwich) 1868, p. 75, pl. ii. fig. 5.

<sup>2</sup> *C. isochela*, H. Woodw. Quart. Journ. Geol. Soc. vol. xxxii. (1876) p. 47, pl. xxxii. figs. 1, 2.

<sup>3</sup> *C. Batei*, H. Woodw. Brit. Assoc. Rep. (Norwich) 1868, p. 74, pl. ii. fig. 4.

## I. MACRURA.

## Tribe THALASSINIDEA.

## Family Callianassidæ.

## Genus CALLIANASSA, Leach, 1814.

1. *Callianassa Whiteavesii*, sp. nov. (Figs. 1 & 2.)

General integument of body extremely thin, or semimembranous, except the first pair of feet, which are protected by a hard covering.

Anterior feet (chelipeds) very unequal; length of larger limb 39 millim.; breadth 9 millim.; the dactylus is straight, and is 9 millim. long, but the fixed thumb of the propodos is rudimentary and stout, being only half as long as the movable finger. Length of smaller hand about 20 millim. Surface of hands faintly wrinkled.

There are indications of the segments of the abdomen and of the thin integument with which they were covered, also of the small thoracic legs, but they are too much broken up for detailed description.

In this species from Vancouver Island the fixed thumb of the propodos is shorter than in any of the species hitherto recorded, and the movable finger (dactylus) is straighter.

The species is smaller than that from the Chalk of Dulmen, Westphalia, or from Maestricht, or Belfast. I have designated it *Callianassa Whiteavesii*, in honour of my friend Mr. J. F. Whiteaves, who has done so much for the elucidation of the Cretaceous formation in Canada.

Original specimens preserved in concretionary nodules of Cretaceous age from Comox River, Vancouver Island. Collected by Dr. C. F. Newcombe (1892). Museum of the Geological Survey of Canada, Ottawa.

A nodule from Vancouver Island, in the Geological Society's Museum, contains the remains of the large hands of *Callianassa Whiteavesii*. A second nodule from the same collection contains the carapace of *Plagiolophus vancouverensis*.

Fig. 1.

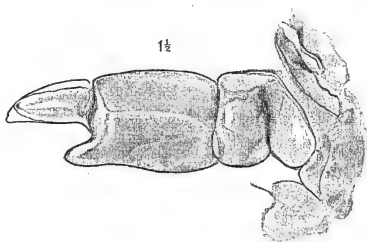
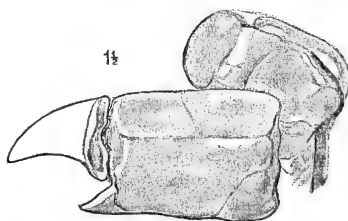


Fig. 2.



## II. BRACHYURA—ANOMALA.

## Family Homolidæ.

## Genus HOMOLOPSIS, Bell.

Carapace longer than broad, quadrilateral; regions of carapace very distinct; branchial region large, triangular; orbits close together, frontal region rather produced; front subrotund.

2. *Homolopsis Richardsoni*, sp. nov. (Fig. 3.)

This interesting little crab was obtained by Mr. James Richardson in 1872 from Skidegate Inlet, west of Alliford Bay, Queen Charlotte Island, and is preserved in a hard black limestone-nodule containing plant-remains. Portions of the limbs still remain in their normal position, showing that it was entire when originally buried in the matrix.

Length of carapace 20 millim., greatest breadth 17 millim.; breadth of posterior border 14 millim.; breadth across hepatic region 14 millim.

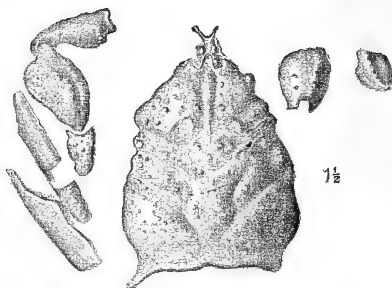
The carapace is broadly quadrilateral, but pointed in front; the branchial regions extend to fully one half the length of the carapace; they are roughly triangular in shape, and nearly meet on the middle line behind the cardiac region; cardiac region small, shield-shaped, but elevated; metagastric region marked by two small prominences; hepatic regions prominent. Two very distinct and almost parallel furrows, the branchial furrow and cervical or hepatic furrow, diverge from the sides of the cardiac and metagastric regions obliquely forward towards the lateral margins of the carapace. Two deep submedian furrows mark the frontal portion of the cephalothorax, reaching to the rostrum, where they converge on the central line. Two small spines (or other appendages) project (as in the genus *Latreillia*) from the rostrum on either side.

The hinder border is extremely wide and straight, and suggests the broad margin for the attachment of the tail as in the females of all the *Anomala*, in which section the abdomen is only partially concealed beneath the cephalothorax.

The surface of the carapace, which is tumid, is coarsely and irregularly covered with small rounded tubercles, which are larger on the gastric and hepatic regions.

The walking-legs were evidently long and fairly large, and the chelipeds curved and tuberculated as in *Homola*.

Fig. 3.



This species has many points of resemblance to Reuss's *Prosopon verrucosum*, from which, however, it differs in the greater anterior breadth of Reuss's specimen, and in the form of the rostrum and arrangement of the furrows upon the gastric and cardiac regions. Reuss's *P. verrucosum* should probably be placed in Bell's genus *Homolopsis*.

In *Homolopsis Edwardsii*, Bell, from the Gault of Folkestone, the frontal border is broader and the carapace more quadrate than in the North American form, which is pointed in front; the anterior half of the carapace in *H. Edwardsii* is more coarsely ornamented with fewer and larger tubercles, and the arrangement of the lobes differs considerably from that in *H. Richardsoni*.

I would refer this specimen to *Homolopsis*, and dedicate the species to the discoverer, Mr. James Richardson.

The specimen is from the Museum of the Geological Survey of Canada, Ottawa.

### Legion OXYSTOMATA.

#### Family Corystidae.

#### Genus PALÆOCORYSTES, Bell.

In this genus the carapace is longer than broad, flattish, becoming narrower gradually towards the posterior border, rostrum short, latero-anterior border dentated. Orbits moderately broad, with two fissures.

The carapace in all the species of this genus at present known is similar to that of the masked crab, *Corystes*, now living on our English coasts.

#### 3. *Palæocorystes Harveyi*, sp. nov. (Fig. 4, p. 226.)

The genus *Palæocorystes*, to which I have referred two of the specimens sent to me by Mr. Whiteaves, is well represented in the Gault, Greensand, Chalk, and Eocene.

Thus we have:—

*Palæocorystes Broderipii*, Mantell, sp.; Gault, Folkestone.

— *Stokesii*, Mantell, sp.; Gault and Greensand, Cambridge and Folkestone.

— *Normanni*, Bell; Chalk Marl, Isle of Wight.

— *Mülleri*, Bink; Upper Chalk, Maestricht.

— *Callianassarum*, Fritsch; Chalk, Bohemia.

— *isericus*, Fritsch; Chalk, Bohemia.

— *glabra*, H. W.; Lower Eocene, Portsmouth.

*Eucorystes Carteri*, M'Coy; Greensand, Cambridge.

Both the specimens from Canada are imperfect. One of them (No. 2) shows the anterior upper surface of the carapace, the other (No. 3) the posterior upper surface. From these we are able to make the following diagnosis:—

*Specific characters.* Length of carapace 35 millim., from the rostrum to the broken posterior border (to this we must probably

add 15 millim. more, making the total length from the rostrum to the posterior border of the carapace 50 millim.); greatest breadth across the hepatic region 37 millim.

(No. 2 was collected by Mr. W. Harvey, Comox River, Vancouver Island, 1892; No. 3 by Dr. C. F. Newcombe.)

Carapace smooth and gently convex in front, and very finely and minutely granulated. Latero-anterior border armed with four serrations on each side, frontal border marked by one prominent and one smaller tooth on either side of the small bifid rostrum, while two fissures mark the margin of each orbit. Under surface of carapace not exposed.

The regions of the carapace are very indistinct; two slightly divergent raised lines about 5 millim. in length mark the frontal region just behind the rostrum, and there is a faint ridge down the centre of the carapace. A small tubercle on either side, behind the frontal region, marks the epigastric lobe. A faint curved and bifurcating line separates the gastric from the cardiac regions, while two slightly rugose and incised lines curve outward and forward from the central cardiac region, marking the limits of the branchial region on either side.

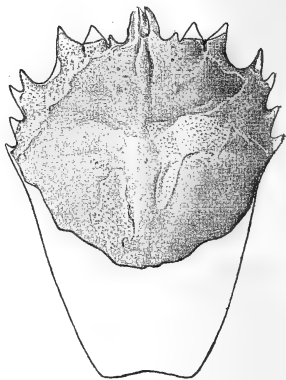
Of the several species of *Palæocorystes* known, the present form, which I have ventured to call *P. Harveyi* after its discoverer, approaches most nearly to *P. Broderipii* from the Gault of Folkestone, but is probably one-third larger. The latero-anterior border of the former (*P. Harveyi*) has four spines on each side, whilst *P. Broderipii* has only two. The orbital regions differ in form, as well as the markings on the regions of the carapace.

We must await more complete materials before attempting a fuller and more careful description; meantime it is interesting to meet with a species from so distant a locality which approaches so nearly to our own Gault species *P. Broderipii*.

*Formation*.—Cretaceous. *Localities*.—Hornby Island (No. 2); and Comox River, Vancouver Island (No. 3).

No. 2 belongs to the Provincial Museum, Victoria, Vancouver Island; No. 3 belongs to the Geological Survey of Canada.

Fig. 4.



#### Legion CYCLOMETOPA.

#### Family Cancridæ.

#### Genus PLAGIOLOPHUS, Bell.

In this genus the carapace is transversely ovate, the regions of the cephalothorax are distinctly marked, front somewhat prominent,



the eyes subdistant, superior border of the orbits with two fissures, etc.

4. *Plagiolophus vancouverensis*, sp. nov. (Figs. 5 & 6.)

This crab is represented by four specimens, three of which I received from Mr. Whiteaves, and the remaining one is preserved in the Museum of the Geological Society.

The carapaces vary in size from :—

	Millimetres	
	long.	broad.
1. Geological Society's specimen .....	22	28
2. From Comox River, Vancouver Island (fig. 5) .....	20	25
3. N.W. side, Hornby Island .....	16	20
4. N.W. side, Hornby Island (fig. 6) ..	10	13

No. 1 and No. 2 are  $\frac{1}{4}$  broader than long, No. 3 is  $\frac{1}{5}$ , and No. 4 is  $\frac{1}{4}$  broader than long.

The frontal border is straight; the rostrum is bifid, with two small rounded elevations divided by a groove; the orbital region is smooth and but little indented; the lateral borders are very gently rounded, the posterior border is nearly straight. The cardiac and metabranchial lobes, the metagastric and epibranchial lobes, and the two mesogastric lobes form three almost parallel lines across the carapace, giving it a very unique linear arrangement; there are also two much smaller lobes, one behind each of the orbits, flanked laterally by a small tubercle, and a small rounded tubercle on each epibranchial lobe; the lateral border was bluntly dentated.

Fig. 5.

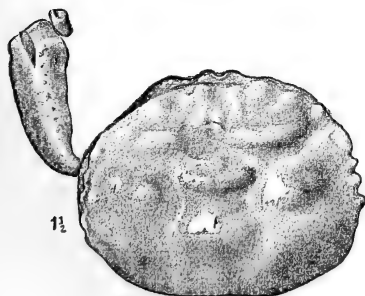
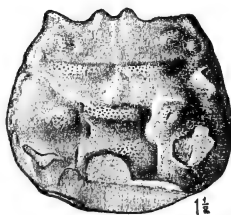


Fig. 6.



When not waterworn (as in specimen No. 4), the surface of the carapace is in parts very finely granulated.

These specimens are very distinct, but without more materials I should not feel justified in separating them generically. I prefer rather to place them in Bell's genus *Plagiolophus*, which was proposed to receive *P. Wetherelli*, from the London Clay of Sheppey.

The same species—described under the name of *Glyphithyreus affinis* (Reuss)—was figured and described by Reuss nearly at the same date. Reuss also adds another species, *Glyphithyreus formosus*, Reuss, from the Upper Cretaceous of Mecklenburg.

I feel satisfied to leave these Vancouver Island crabs in this genus, and to designate them by the trivial name of *vancouverensis*.

Two specimens were collected on the north-western side of Hornby Island, and one on Comox River, Vancouver Island, British Columbia. The locality of the Geological Society's specimen is not marked, but it is from Vancouver Island.

Nos. 3 and 4, from Hornby Island, belong to the Provincial Museum of Victoria, Vancouver Island.

No. 2 specimen shows traces of limbs, and the flattened propodos of a chelate fore-arm 13 millim. long  $\times$  8 millim. broad.

10. *On a FOSSIL OCTOPUS (CALAÏS NEWBOLDI, J. De C. Sby. MS.) from the CRETACEOUS of the LEBANON.* By HENRY WOODWARD, LL.D., F.R.S., F.G.S. (Read January 22nd, 1896.)

## [PLATE VI.]

I AM indebted to Mr. C. Davies Sherborn, F.G.S., for drawing my attention to a very remarkable and beautiful fossil from the Cretaceous formation of the Lebanon, Syria, obtained about 1846 by Lieut. T. J. Newbold, and presented by him to the Museum of the Geological Society, where it has since remained. In 1846 it attracted the attention of Mr. J. De Carle Sowerby, who evidently intended to describe it, 'at a more convenient season,' which never arrived; for he wrote upon it:—

'*Calais Newboldii*' (read *Newboldi*). 'CEPH. OCTOPODA. Genus *ineditum*. Abdomen *alis triangularibus instructum*.

'*Estrato calcareo tertiariorum Montis Libani a D. (T. J.) Newboldi effossum* 1846. J. DE C. SOWERBY.'

The only criticisms that I would venture to make upon this label are (1) that the stratum of limestone from the Lebanon, whence the fossil was derived, is not of 'Tertiary' but Cretaceous age; (2) that the specimen is marked in pencil on the back 'Major Newbold, Mt. Lebanon' (whose initials were 'T. J.' = 'Thomas John') not *D.*, and there should be no *u* in Newbold. He is spoken of in 1842 as 'Lieut. Newbold' (Proc. Geol. Soc. 1842, pp. 782-792), and by Murchison in his Presidential Address, Feb. 17th, 1843, as 'Lieut. Newbold, of the East India Company's service' (Proc. Geol. Soc. vol. iv. 1846, p. 137).

[In the 'National Biography,' 1894, pp. 314-315, Newbold is spoken of as one of the most accomplished officers in the East India Company's service. He was made a Lieutenant in 1834; and, while serving in Malacca, was Aide-de-camp to Brigadier-General E. W. Wilson, C.B. In 1840 he obtained leave and visited Egypt, Sinai, and Palestine, when he no doubt secured the fossil now under consideration. He was made a Captain, April 12th, 1842; but his later rank of Major is not mentioned by his biographer. He died at Mahabuleshwar on May 29th, 1850, at the age of 43 years. He wrote several important works on Indian Geology, on Egypt, the Sinaitic Peninsula, and Palestine, and he contributed 46 papers to various learned Societies.]

Prof. Lewis says, 'There are two principal localities for Cretaceous fossils known and recorded in the Lebanon, namely, Hâkel and Sahel-el-Alma, and a third of minor importance, called Hazhûla (Djoula on the French military chart), about 2 hours and a half south of Hâkel.

'Hâkel is the oldest known locality, though it has been but rarely visited. It is a long day's journey from Beirût, and is situated at about 800 to 1000 feet of elevation above the sea, and distant from the sea in a straight line about 6 miles.

'Sahel-el-Alma is nearer to Beirût, and may be visited from the

latter place in one day, with an allowance of two or three hours at the locality.

'The rock at Hâkel is somewhat harder than from Sahel-el-Alma, very fissile, and can be readily trimmed with the hammer.

'The section at Sahel-el-Alma is under the very walls of the old Convent, which gives its name to the spot; here, in a fig-orchard, outcrops the stratum of white chalky limestone where so many beautiful fossils have been obtained, and whence comes also the *Calais Newboldii*.'

The following is a brief summary of the bibliography of this classical locality:—

The existence of fossil fishes in the Lebanon is referred to in Joinville's 'Histoire de St. Louis'—edited by M. Natalis de Wailly. During the sojourn of the king at Sidon in 1253, just before his return home from the Crusades, a stone was brought him, says Joinville, 'which was the most marvellous in the world, for when a layer of it was lifted, there was found between the two pieces the form of a fish. The fish was of stone, but lacked nothing in form, eyes, bones, colour, or anything necessary to a living fish. The king demanded a stone and found a tench within.'

M. de Blainville described *Clupea brevissima* and *Clupea Beaurardi*, from Hâkel, in the Lebanon, in 1818.

Mr. Chas. Koenig, 1820, in his 'Icones Fossilium sectiles,' figured *Ophiura libanotica* and *Euryale Bajeri*, pl. ii. figs. 26 and 27, from the Cretaceous of the Lebanon.

Prof. L. Agassiz, in 1833–43 ('Poissons fossiles'), described two species of *Clupea* from Hâkel, and a *Sphyræna* and *Rhinellus* from Sahel-el-Alma.

Sir Philip Egerton added an account of *Cyclobatis* from Hâkel (Quart. Journ. Geol. Soc. vol. i. p. 225) in 1845.

Prof. Haeckel described two species of *Pycnosterinx* from Sahel-el-Alma, and a new species of *Clupea* from Hâkel, in 1849.

Mr. O. G. Costa described *Imogaster*, *Omosoma*, and *Beryx* in 1855.

In 1866 MM. Pictet and Humbert ('Nouvelles Recherches sur les Poissons fossiles du Mont Liban') described 26 species of fishes from Sahel-el-Alma and 21 from Hâkel.

(*Leptosomus macrurus*, described by Pictet and Humbert, Upper Cretaceous, Sahel-el-Alma, Mount Lebanon, is one of the fishes associated on the same slab with *Calais Newboldi*, the subject of this paper.)

Dr. Louis Lartet, in his fine memoir, 'Exploration géologique de la Mer Morte, de la Palestine et de l'Idumée' (1877), recorded, at p. 112, CLASS CEPHALOPODA. 1. OCTOPODA, '*Calais Newboldii*,<sup>1</sup> Sow. Empreinte de Céphalopode dans les Calcaires à Poissons du Liban (Collection de la Société géologique de Londres).'

Lartet also mentions the remains of cephalopods of the family Sepiadæ from the same Cretaceous Limestone of the Lebanon (preserved in the Paris Museum).

<sup>1</sup> (The *z* in the specific name should be omitted.) 'Cette empreinte curieuse, très-bien conservée, a été recueillie par M. Newbold.'

Prof. Dr. Oscar Fraas, in his work, 'Aus dem Orient,' 1878, pt. ii. (Stuttgart), figures and describes 28 species of invertebrata, echinodermata, mollusca, crustacea, etc., and 1 fish (*Gyrodus*) from the Cretaceous of Syria. He figures one dibranchiate cephalopod (*Geoteuthis libanoticus*) and 1 ammonite.

Dr. Fraas mentions that he saw in the collection of the Rev. Prof. E. R. Lewis, at the Syrian Protestant College, Beirût, a specimen of *Sepialites* with eight arms, of which he secured a photograph; and that Sowerby had long ago obtained from the Lebanon an *Octopus* collected by Mr. Newbold, to which he had given the name of *Calais Newboldi* ('Aus dem Orient,' ii. p. 90).

In the same year (1878) the Rev. Prof. Lewis, F.G.S., gave an interesting description of the Fossil Fish Localities of the Lebanon in the Geological Magazine (pp. 214-220).

In 1879 I described before this Society *Squilla Lewisii* and *Limulus syriacus* from the Lebanon Cretaceous (see Quart. Journ. Geol. Soc. vol. xxxv. pp. 552-556, pl. xxvi.).

In 1883 I described a new genus of fossil 'Calamary,' *Dora-teuthis syriacus*, from the Cretaceous of Sahel-el-Alma (see Geol. Mag. 1883, pp. 1-5, pl. i.).

In 1882 Mr. W. H. Hudleston, F.R.S., gave in his Presidential Address to the Geologists' Association an admirable account of the 'Geology of Palestine,' in which the geological horizon of the Hâkel and Sahel-el-Alma deposits is discussed, with a coloured map and a plate (Proc. Geologists' Association, vol. viii. 1883-84, pp. 1-53) (see also 'Further Notes,' Proc. Geol. Assoc. vol. ix. 1885, pp. 77-104).

In 1886 Prof. Dr. W. Dames published an account of ten genera and twelve species of crustacea from the Cretaceous of the Lebanon. Among them is one figured and described as *Protozoëa Hilgendorfi*, Dames, which is represented by three specimens on the slab which contains *Calais Newboldi* (Zeitschr. d. deutsch. geol. Gesellsch. vol. xxxviii. 1886, p. 577, pl. xv. figs. 5-7).

The fossil remains of *Calais Newboldi* are preserved as a delicate ferruginous impression upon the biscuit-coloured surface of one of the fissile slabs of Cretaceous Limestone from Sahel-el-Alma, Mount Lebanon.

The slab is  $9\frac{1}{2}$  inches long by 8 in breadth and 1 in thickness, displaying remains of fossil organisms upon both its surfaces.

These consist of several small well-preserved fishes, *Leptosomus macrurus*, Pictet & Humbert, and a small crustacean carapace (believed to be a zoea-form) and named *Protozoëa Hilgendorfi* by Dames.

The *Octopus*, which occupies the centre of the slab, exhibits its eight arms (or more properly feet or 'podites'), each furnished with a row of suckers, which diminish in size gradually from their base to the very slender extremities of the podites. Near the union of the podites with the head, there is a faint trace of what

may have represented the umbrella, or 'web,' which once united the arms or podites together.

In the centre of the head (between the bases of the arms or podites) is a darker and denser spot of brown showing evidence of the beaks,—marking the position of the mouth; below this again is a small slightly-raised orifice, which probably marks the opening of the funnel. Two remains of fishes lie across the neck and separate the head and arms above from the round wrinkled body beneath, with its triangular fins, a feature which at once distinctly characterizes this genus.

An injudicious attempt to develop the two mutilated fishes, lying across the Octopod, has resulted in the unfortunate removal of a part of the thin and delicate layer on which the Nature-painting of *Calaïs* was preserved. In the centre of the body is an oval depression or cavity 8 mm. long and 4 mm. broad, once occupied by the ink-bag. The breadth of the body is 40 mm., and to the extremity of the lateral fins 64 mm.; height of fin 14 mm. Length of arms rather over 100 mm. Breadth of arm near the head about 5 mm., but diminishing rapidly to 4 and 3 mm., and terminating in a slender whip-like extremity.

There appears to be only a single row of suckers upon each arm, as in the genus *Eledone*, and about 30 suckers in each row. The suckers vary in size from 2 mm. in diameter to less than 1 mm. Some of the suckers seen in profile stand up as much as 2 mm. from the surface of the arm.

There is a faint trace of the presence of an umbrella, or web, uniting the bases of the arms around the mouth to a distance of about 15 mm. The arms were evidently very flexible, judging by the graceful curves which they have assumed even in death. They are also seen to be of nearly equal size and length, so far as can be ascertained.

As I have already stated, the triangular 'alæ,' or more properly 'fins,' are characteristic of *Calaïs*. S. P. Woodward ('Manual of the Mollusca,' p. 64) says of the Octopods, 'their bodies are round, and they seldom have fins.'

In *Pinnoctopus* the body has lateral fins united behind (ex. *P. cordiformis*). In *Cirroteuthis* the body has two transverse fins. In *Calaïs*, as we have seen, the body is round, but it is provided with triangular lateral fins (not united behind).

In the decapoda—cephalopods with eight arms and two tentacles, or, as they are often called, 'tentacular arms'—the body is oblong or elongated, and is always provided with a pair of lateral or nearly terminal fins.

*Sepiolo* has rounded dorsal fins, but in very many genera the fins are terminal and often rhombic or angular.

The question of the position of the arms, whether uniform in size and freely-moving, or differing in size and position in relation to the dorsal and ventral aspect of the body, is of some importance even in studying these fossil remains.

Thus, for example, in his work, 'Aus dem Orient,' vol. ii. p. 90,

Dr. Fraas refers to a specimen which he had seen at Beirût in the collection of the Rev. Prof. Lewis; this showed the head of a sepialite with its eight arms close together, and, as he says, reminded him of the fossil forms from the Lias, figured and described by Quenstedt.

Dr. Fraas obtained a photograph of this 'sepialite' from Prof. Lewis, which was afterwards lent to Mr. G. C. Crick, F.G.S., who compared it with specimens obtained by the British Museum from the late Prof. Lewis, and was happily able to identify by its aid the original of Dr. Fraas's remarks.<sup>1</sup>

The specimen proves to be the head and arms of a decapod cephalopod allied probably to *Onychoteuthis*, showing the eight ordinary arms, but with only a faint trace preserved of one of the long tentacular arms.

The arms are close together and nearly straight, and are arranged in pairs. First there is a pair of slender and short dorsal arms, then two pairs of

very stout and longer lateral arms, and, lastly, another pair of somewhat shorter and more slender ventral arms.

No suckers are visible on the arms, but there are traces of what appear to be hooklets and serrations in two or three places, so that, taken in connexion with the more rigid carriage of the arms and their arrangement in pairs, we may feel assured that

*Plesioteuthis Fraasii*, *sp. nov.*, from the Cretaceous of the Lebanon.



this is not an octopod, like *Calais*, but a true Teuthid<sup>2</sup> and probably related to *Dorateuthis* (see Geol. Mag. 1883, pl. i. p. 1).

<sup>1</sup> The photograph was marked in pencil *Calais Newboldi*.

<sup>2</sup> If a name be desired, I would suggest for this sepialite the name of *Plesioteuthis Fraasii*, after the author of 'Aus dem Orient.'

Length of the largest arms 7 inches, of the shortest pair of dorsal arms 4 inches; the second or ventral pair of slender arms are 5 inches long. The head with the arms is nearly 10 inches in length. The beak is  $\frac{3}{4}$  inch in length and  $\frac{1}{12}$  inch broad at its base.

At present, so far as my information serves, *Calais Newboldi* remains the oldest and only known fossil octopod.

I have retained Mr. J. de Carle Sowerby's original name, it having been already recorded in print by Dr. Oscar Fraas and by Dr. Louis Lartet in their respective works already referred to.

The genus *Cālāis* is derived from Cālāis, the brother of Zetes (sons of Boreas and Orithyia), frequently called the Borēādæ (mentioned among the Argonauts), and described as winged beings. [Smith's Classical Dictionary, 1883.]

#### POSTSCRIPT.

The genus *Dorateuthis*, proposed by myself in 1883, is by Zittel included in the genus *Plesioteuthis* of A. Wagner (1860), which has also a tricarinate internal pen with a spatulate distal expansion.

There are now in the British Museum (Natural History) as many as ten *Teuthidæ*,<sup>1</sup> the largest of which is 20 inches in length, and exhibits the body, head, and arms in union. The smallest is not so large as *D. syriacus*, H. W. (1883). They all possess tricarinate shells.

I hope to offer some further notes upon these very well-preserved decapod cephalopoda from the Lebanon later on, with the promised kind co-operation of Mr. G. C. Crick, F.G.S., who has devoted so much attention to the cephalopoda generally, and to whom I am indebted for information and assistance in preparing this paper.

#### PLATE VI.

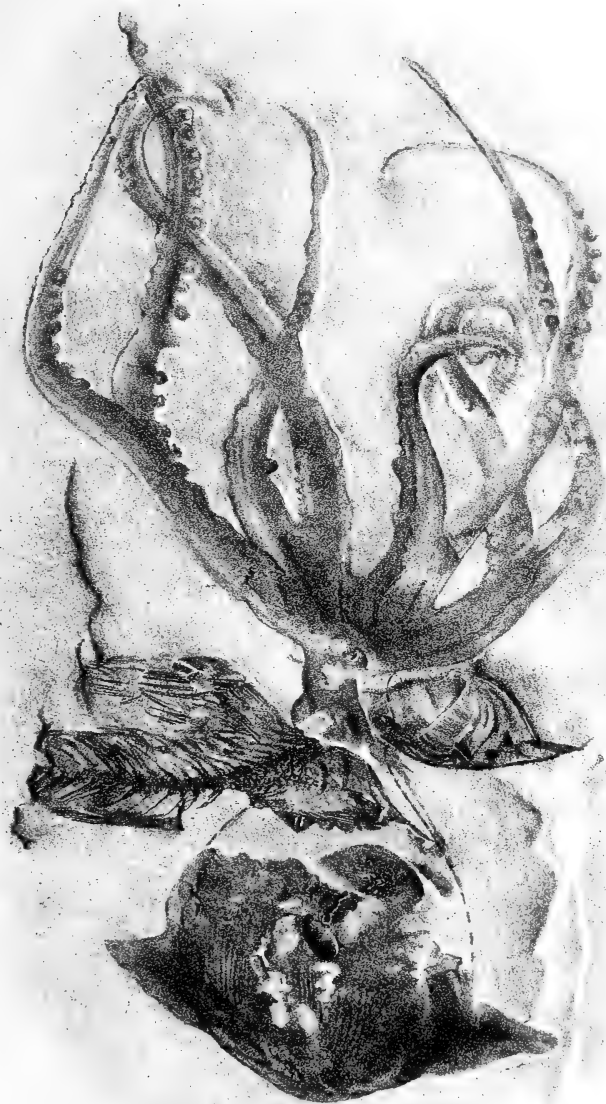
*Calais Newboldi* from the Cretaceous of the Lebanon.

#### DISCUSSION.

Mr. CRICK stated that, as the occurrence of this fossil had been already at least twice recorded, and as neither a description nor a figure had been given hitherto, it was most important that the specimen should be described and figured, and it was very fortunate that the fossil had come into the hands of the President for description. He believed the specimen to be a true octopod; it was therefore the oldest known representative of this division of the cephalopoda.

<sup>1</sup> All from Prof. Lewis's collection of Lebanon Cretaceous fossils.







11. *The BRITISH SILURIAN SPECIES of ACIDASPIS.* By PHILIP LAKE, Esq., M.A., F.G.S. (Read December 18th, 1895.)

[PLATES VII. & VIII.]

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I. INTRODUCTION.

THE genus *Acidaspis* has been a peculiarly unfortunate one in Britain. Several of the specific names which are in common use are manuscript terms, or but little better; and the species to which they are applied have never been described. It is impossible, therefore, without access to standard collections, to determine to what forms the names refer. Even the species which have been described have in many cases been imperfectly figured, and the result is endless confusion. The common English trilobite, *A. coronata*, has received abroad no less than three names, all of them different from ours; while in England, on the other hand, the foreign name *A. crenata* is often applied to a species which is quite distinct from the original *A. crenata*, and which in fact has never yet been found out of Britain.

The disorder is worst among the Silurian forms, although these are much the most perfect. The Ordovician species are usually fragmentary, but the fragments have been fully described.

It is the object of the present paper to attempt to reduce the specific terminology to some sort of order, and to rescue the common manuscript names from the obscurity in which such terms tend to become involved after a lapse of time. Only the Silurian forms are here described; the Ordovician species have been left in the hope that better material may be forthcoming in the future.

Even the name of the genus itself is matter of controversy. Murchison<sup>1</sup> employed the term *Acidaspis* in 1839, and in the same year Emmrich<sup>2</sup> proposed the name *Odontopleura*. The latter is often used in Germany, but the former is the more widely spread. There is, however, an earlier name still, the use of which has been advocated by Vogdes<sup>3</sup> and J. M. Clarke,<sup>4</sup> though Vogdes, in his bibliography,<sup>5</sup> does not adopt his own suggestion. This name is *Ceratocephala*, and was applied by Warder<sup>6</sup> in 1838 to a species which he called

<sup>1</sup> 'Silurian System,' p. 658.

<sup>2</sup> 'De Tril. Diss. inaug.' 1839, Berlin.

<sup>3</sup> Proc. Acad. Nat. Sci. Philadelphia, 1877, p. 138.

<sup>4</sup> 44th Ann. Rep. New York State Museum (1891), p. 91.

<sup>5</sup> Bibl. Pal. Crust. 1893, San Francisco.

<sup>6</sup> Amer. Journ. Sci. & Art, vol. xxxiv, no. 2 (1838), p. 377.

*Ceratocephala goniata*, and which belongs to the same group as *A. vesiculosa* etc. Warder's name was rejected by Corda on the ground that it had already been employed, in the form *Ceratocephalus*, for a genus of plants; but even if it be eligible, its rival, *Acidaspis*, has been so widely used for so long a time that, here at least, I do not propose to adopt any other.

## II. DESCRIPTION OF SPECIES.

### ACIDASPIS BRIGHTI, Murch. (Pl. VII. fig. 5.)

1839. *Acidaspis Brightii*, Murch. 'Sil. Syst.' p. 658, pl. xiv. fig. 15; 1848. Salter, Mem. Geol. Surv. vol. ii. pt. i. p. 348, pl. ix. figs. 6(?), 7 (not figs. 8, 9).  
(Not *Odontopleura Brightii*, Beyrich, 'Unters. über Tril.' p. 20, pl. iii. fig. 6.)

Head transverse, crescentic, with one occipital and two genal prolongations or arms; tuberculate. Glabella prominent; central portion nearly uniform in width throughout, but slightly contracted between the second pair of lateral lobes; lateral lobes two on each side, almost completely separated from the central portion; the basal lobe much the larger of the two. Occipital ring very indistinctly separated from the glabella, produced backward into a single, strong, straight median spine. Eyes placed far back, and very near to the basal lobe of the glabella; connected with the front end of the glabella by a nearly straight ocular ridge. Free cheeks small, with a raised margin, which bears a number of spines directed downward; genal angles produced into long and strong spines, which form a continuous curve with the posterior margin of the head, but make a distinct angle with the external margin.

*Horizons and Localities.*—Wenlock Limestone: Dudley. Lower Ludlow: near the Wych, Malvern. It has been recorded from the Bala beds, but this is probably due to mistaken identification.

*Affinities.*—Only the head is known with certainty. It closely resembles *A. Grayi*, Barr., but is distinguished, as Barrande has pointed out, by the following characters:—(1) the genal spines in *A. Brighti* are inclined to the axis at an angle of about 45°, while in *A. Grayi* they are nearly at right angles to it; (2) the occipital spine in *A. Brighti* is usually somewhat smaller than in *A. Grayi*, and does not bear the prominent tubercle characteristic of the latter; (3) the ocular ridge in *A. Brighti* is nearly straight, in *A. Grayi* strongly arched; (4) the granulation in *A. Brighti* is much coarser and stronger than in *A. Grayi*.

It is easily distinguished from all other British species by the single strong occipital spine.

*Remarks on the Synonymy.*—The species was originally described and figured by Murchison, and formed the type of his genus *Acidaspis*. In 1848 Salter gave a fuller account of the form; but unfortunately he confounded two species under the same name, and figured two distinct heads and two distinct tails. One of the species is identical with *Paradoxides quadrimucronatus*, Murch., and hence this name is usually quoted as a synonym of *A. Brighti*. Subsequently Salter recognized his error, and in 1857 he described the

second species under the name of *A. coronata*. This, and not *A. Brightii*, is the *Paradoxides quadrimucronatus* of Murchison.

Beyrich's *Odontopleura Brightii* is a different species, and is identical with *Acidaspis quinquespinosa*, Salter MS.

### ACIDASPIS CORONATA, Salter. (Pl. VII. fig. 6.)

1839. ? *Paradoxides quadrimucronatus*, Murch. 'Sil. Syst.' p. 658, pl. xiv. fig. 10.

1845. ? *Odontopleura mutica*, Emmrich, Neues Jahrb. 1845, p. 44; 1846. Beyrich, 'Unters. üb. Tril.' p. 19, pl. iii. fig. 5.

1848. *Acidaspis Brightii* (pars), Salter, Mem. Geol. Surv. vol. ii. pt. i. p. 348, pl. ix. figs. 8, 9 (not figs. 6, 7).

1853. *Acidaspis coronatus*, Salter, Mem. Geol. Surv. dec. vii. pl. vi. p. 7; 1854. Morris, 'Catalogue of Brit. Fossils,' 2nd ed. p. 99.

1854. *Acidaspis Marklini*, Angelin, 'Pal. Scand.' p. 38, pl. xxii. fig. 13.

1854. *Acidaspis multicuspis*, Angelin, 'Pal. Scand.' p. 37, pl. xxii. fig. 12.

1857. *Acidaspis coronata*, Salter, Quart. Journ. Geol. Soc. vol. xiii. p. 210.

1885. *Acidaspis Marklini*, Lindström, Öfv. kongl. Vet.-Akad. Förh. Arg. 42, no. 6, p. 54, pl. xiii. figs. 8, 15, pl. xvi. fig. 10.

1888. *Acidaspis mutica*, Wigand, Zeitschr. deutsch. geol. Gesellsch. vol. xl. p. 93, pl. x. figs. 19, 20.

General form broadly ovate, depressed.

Head large, semilunar, the angles drawn out into broad spines; granulate. Glabella triangular; median portion nearly parallel-sided; the basal lateral lobe is considerably larger than the second; both are rounded and well-defined, but confluent on the inner side with the median portion of the glabella; anterior lateral lobes obsolete. Frontal border nearly straight, smooth, projecting beyond the margin of the free cheeks. The facial suture in front of the eye is nearly parallel to the axis, behind the eye is continued almost at right angles, and cuts the posterior margin not far from the genal angle. Eyes small, prominent, placed far back, close to the occipital furrow; ocular ridge curved. Free cheeks easily separable, granular, steeply inclined, bearing at the margin a row of about twelve short spines; produced at the genal angles into broad spines, the borders of which are nearly continuous in direction with the borders of the cheeks.

The thorax consists of ten segments. Axis narrow. Pleuræ straight, at right angles to the axis; produced into spines, which are strongly bent backwards. Each pleura bears a prominent ridge, on which is a row of small tubercles, sometimes indistinct. The spines also are granulate.

Tail broad, short. The axis consists of two segments. From the anterior ring a strong rib proceeds on each side to the margin, where it is produced and forms a primary spine. There are four secondary spines between the two primaries, and one outside each. All the spines are directed straight backward, and they are generally short. The margin, spines, and other prominent parts bear tubercles, and there is generally one somewhat larger than the average, at the base of each spine.

*Horizons and Localities*.—Wenlock Limestone: Dudley; Walsall; Malvern; Pen-y-liau, Cardiff. Lower Ludlow: Vinnal Hill, Ludlow; Dudley. A very much crushed specimen in the Museum of Practical

Geology, Jermyn Street, from the Upper Llandovery of Pen-y-llan, seems to belong to this species.

*Affinities*.—This species closely resembles *A. deflexa*, from which, however, it may be distinguished by the following characters:—(1) the external border of the genal spine in *A. coronata* forms a curve nearly continuous with the external margin of the cheek; in *A. deflexa* there is a distinct angle between the two; (2) the tail of *A. coronata* bears eight short points, all of which are parallel to the axis, while the tail of *A. deflexa* bears only four spines and a rudimentary point at each of the anterior angles.

*Synonymy*.—*A. coronata* has been one of the most unfortunate species of an unfortunate genus. At the present day it bears three distinct names, all of which are in common use. It is known as *A. coronata* in England, *A. Marklini* in Sweden, and *A. mutica* in Germany; and even yet it is not clear which of these names it ought to bear. Murchison's term *quadrimucronatus* is older than any of them; but it is so entirely misleading, and his description is so incorrect, that although his figure is just recognizable, the name can scarcely stand. Moreover, it is possible that all palæontologists may not consider Murchison's figure unmistakable.

The oldest of the other three names is *mutica*; but although our species is identical with *A. mutica* as figured and described by Wigand, it is by no means certain that it is the same as *Odontopleura mutica* of Emmrich and Beyrich. Emmrich's description is too brief to be of any value; but Beyrich's account of the species states that the thorax has only 9 segments, while in his figure the spines of the tail are radiate instead of parallel. Until, therefore, Emmrich's or Beyrich's type has been re-examined, it is impossible to apply the name to the English form.

In 1848 Salter figured and described *Acidaspis Brightii*, Murch., but unfortunately, along with a specimen of the true *A. Brighti*, he figured also a head and a tail of our present species. In 1853 he had discovered his mistake, and proposed the name *coronatus* for the new form, pointing out at the same time which of his figures belonged to it; but it was not till 1857 that he published a description.

In the meantime Angelin had described and figured the thorax and tail of the same trilobite as *A. Marklini*, a name which has not unnaturally been accepted in Sweden. Under the impression that it belonged to a distinct species, he gave to the head of this form the name of *A. multicuspis*. Angelin's figures are not good, but Lindström has since given an accurate description of the species with good figures; and from an examination of the original specimens in the Riksmuseum at Stockholm I am able to state that the Swedish and English species are identical.

Thus there is plenty of room for difference of opinion, and it is not without hesitation that I have adopted Salter's name. But, putting aside Murchison's term, Salter's was the first which was applied to a recognizable figure of the species.

*ACIDASPIS DEFLEXA*, sp. nov. (Pl. VII. fig. 7.)

This resembles *A. coronata* so much that a full description is unnecessary, and it will be sufficient to draw attention to the chief points of difference.

Head as in *A. coronata*; but the genal spines are more slender, and their outer borders make a distinct angle with the external margin of the cheek.

The thorax consists of ten segments, as in *A. coronata*; but the pleural spines are somewhat more delicate.

Tail rather large, broad. Axis small, with two rings defined upon it; from the anterior ring a rib curves back on each side, and is produced beyond the margin of the tail as a long slender spine, slightly inclined outwards. Between these two primary spines are two shorter ones, and outside each primary is a rudimentary point.

*Horizon and Localities.*—Wenlock Limestone: Dudley; Walsall.

*Affinities.*—This is one of the forms which are commonly called *A. crenata* in England; but it is quite a distinct species, and is much more closely allied to *A. coronata*. From *A. crenata* it is distinguished by the outline of the head, the strength of the genal spines, the absence of crenation on the frontal border, etc. From *A. coronata* it is separated by the characters of the genal spine and of the tail, as described above.

*ACIDASPIS CRENATA*, Emm. sp. (Pl. VII. figs. 1 & 2.)

1845. *Odontopleura crenata*, Emmrich, Neues Jahrb. 1845, p. 44.

1845. *Ceraurus crenatus*, Lovén, Öfv. kongl. Vet.-Akad. 1845, p. 47, pl. i. fig. 1.

Body oval, broad in front, narrowing rapidly behind.

Head sub-quadrate, about twice as broad as long, margin incurved in front. The glabella narrows slightly towards the front; basal and second lobes rounded, nearly equal in size, almost completely cut off from the central part of the glabella. The occipital ring bears a small tubercle. Frontal border crenate. Facial suture in front of the eye nearly parallel to the axis, behind the eye it cuts the posterior margin. Eyes very prominent, placed far back, close to the neck furrow and near to the glabella. Free cheeks granular; margin provided with short spines; genal angle produced into a long slender spine, which at its origin is curved outward.

The thorax consists of nine segments, which after the first two or three decrease in width towards the tail. Axis about as wide as the pleuræ. Pleuræ nearly at right angles to the axial line; each bears a prominent ridge, which, except in the case of the first two segments, is produced into a long, slender, backwardly-directed spine.

The tail exists in two forms (each of which has been found attached to a complete specimen):—(1) very small; consists of two segments, the anterior of which is produced backward into a long spine on each side; two very short spines between these primaries; (2) much broader, with a broad flat area around the axis; primary spines not so long, secondary spines larger. These two forms probably belong to different sexes.

*Horizon and Locality.*—Wenlock Beds: Dudley.

*Affinities.*—As already remarked, *A. deflexa* has usually been mistaken for *A. crenata*; but the resemblance is not very striking, and the differences have already been noted. *A. Barrandeii*, Ang., is very close to *A. crenata*, and indeed is only distinguished by the presence of a pair of tubercles on each ring of the axis and on each pleura. Several of the British specimens show tubercles upon the axis and pleuræ. The presence or absence of these tubercles is probably not a character of specific value, and depends, in part at least, upon whether the actual test of the animal is preserved.

The specimens of *A. crenata* in the Riksmuseum at Stockholm show both forms of tail. Lovén's figure belongs to the narrow-tailed variety.

*ACIDASPIS QUINQUESPINOSA*, Salter MS. (Pl. VII. figs. 3 & 4.)

1846. *Odontopleura Brightii*, Beyrich, 'Unters. üb. Tril.' p. 20, pl. iii. fig. 6.

1854. *Acidaspis quinquespinosus*, Fletcher & Salter, in Morris's 'Catalogue of Brit. Fossils,' 2nd ed. p. 99; 1873. Salter 'Cat. Cambr. & Sil. Foss.' p. 134.

Body broadly ovate.

Head short, broad, nearly straight in front; surface tuberculate. Glabella triangular, occupying at the base about one-third the width of the head; three pairs of lateral lobes separated one from another by lateral furrows, but not cut off from the median part of the glabella. The facial suture, represented by a raised ridge, runs in a straight line from the anterior margin to the eye and thence in a sigmoid curve to the genal angle. Eyes small, set somewhat behind the middle of the cheeks; a straight ocular ridge runs from each to the anterior corner of the glabella. Fixed cheeks broad, the portion between the ocular ridge and the glabella tumid. Free cheeks with a raised margin, which bears a row of short spines; produced at the genal angle into a short curved spine. Axial part of occipital ring broad, and bearing on its posterior margin five small spines; the posterior margins of the cheeks each bear two spines, exclusive of that at the genal angle.

The thorax consists of ten segments, and is broader than it is long. Axis very broad, more than one-third the total width. Pleuræ horizontal till near the margin, when they are abruptly bent downward and then produced into short curved spines; the anterior pleuræ are at right angles to the axial line, the posterior pleuræ slightly inclined backward, and this is true, in a more marked degree, of the spines. Each pleura bears a prominent tuberculate ridge.

Tail short, broad, forming a segment of a circle; it bears one curved ridge on each side, which is produced to form a short primary spine. Outside each primary spine are two secondaries; and between the primaries are four secondaries. Margin of tail raised.

*Horizon and Locality.*—Wenlock Limestone: Dudley.

It is on the authority of specimens in the Woodwardian



Museum, referred to in Salter's 'Catalogue,' that the name is applied to the species here described.

*ACIDASPIS BARRANDEI*, Fletcher & Salter, *non* Angelin. (Pl. VIII. figs. 1-3.)

1848. *Acidaspis bispinosus*, Salter, Mem. Geol. Surv. vol. ii. pt. i. pl. ix. fig. 4 (only).

1853. *Acidaspis Barrandii*, Fletcher (*dixit* Salter), Mem. Geol. Surv. dec. vii. p. 6, pl. vi.; 1854. Fletcher & Salter, in Morris's 'Catalogue of Brit. Fossils,' 2nd ed. p. 98; 1859. Murchison, 'Siluria,' 3rd ed. p. 261, Foss. 64, fig. 9.

General form quadrate, nearly as wide behind as in front.

Head quadrate, widest in front, tuberculate. Axal furrows almost obsolete; median portion of glabella swollen, narrows slightly towards the front; two pairs of lateral furrows deeply impressed; lateral lobes very indistinctly separated from the cheeks. Facial suture invisible. Eye small, prominent, set in the middle of the cheeks; ocular ridge straight. Fixed cheeks large and tumid. The free cheeks widen out towards the front, with a broad tuberculate raised margin bearing a row of short spines. Moderately long slender spines at the genal angles, but these do not appear to spring from the margin. The axal part of the occipital ring is produced into a pair of spines directed backward and outward.

The thorax consists of ten segments. Axis wide; each segment bears two prominent tubercles. Pleuræ broad, flat, tuberculate; at a distance from the axis about equal to the width of the axis, all but the last are abruptly bent downward and produced into a short ornamented spine (very rarely visible); and from the angle of the bend long horizontal spines are given off. The horizontal spines are arranged in a radiate fashion, those from the anterior segments being directed slightly forward, and those from the posterior segments backward. The last segment differs from these, and bears two ornamented horizontal spines on each side.

Tail broad, tuberculate; axis ill-defined. The margin bears five longer spines, one being median, and from the front of the base of each lateral spine is given off a smaller ornamented spine, thus making a total of nine.

*Horizon and Locality.*—Wenlock Limestone: Dudley, Callow Farm.

*Affinities.*—*A. Barrandei* is closely allied to *A. Verneuli*, Barr., and *A. vesiculosa*, Beyr., and in fact is chiefly distinguished by the characters of its tail. *A. vesiculosa* has five spines to its tail, *A. Verneuli* seven, and *A. Barrandei* nine.

*A. bicuspis*, Ang., belongs to the same group. Only one specimen, which is now in the Riksmuseum at Stockholm, appears to have been found, and it is scarcely perfect enough to allow of one's asserting with confidence whether it is a distinct species or not.

*Synonymy.*—The head of this species was originally figured by Salter in 1848 under the name *A. bispinosus*. In 1853 he corrected his mistake, and stated that the form had been named *A. Barrandii* by Fletcher, and would shortly be described. Since then this name has been in common use in England; but no description seems

ever to have been published. Unfortunately, in 1854, Angelin adopted the name *A. Barrandei* for a species quite distinct from this, and allied to *A. crenata*. As, however, Fletcher's name had already been published and applied to a definite figure, it would appear to have priority.

ACIDASPIS HUGHESI, Salter MS. (Pl. VIII. figs. 4 & 5.)

1873. *Acidaspis Hughesii*, Salter, 'Cat. Cambr. & Sil. Foss.' p. 93.

General form depressed, broadly ovate.

The head forms a transverse semi-oval. The glabella consists of a parallel-sided median portion and two lateral lobes on each side, completely cut off from the median portion; the basal lobe is much the larger. The facial suture cuts the posterior margin just within the genal spine. Eyes small, set somewhat far back. Fixed cheeks narrow, tumid. Free cheek broad, granulate, provided with a raised margin bearing a row of spines, which become longer towards the genal angle; genal angle produced into a short weak spine directed backward and outward. The axis of the neck-segment bears two short spines, which are seldom visible.

The thorax consists of nine segments, and is of nearly equal width throughout. Axis narrow, about one fourth the total width of the body. Pleuræ straight; the greater part of each is occupied by a broad prominent ridge, which bears a row of some half-dozen tubercles; on each side of this main ridge is a very narrow band, the anterior one being somewhat the broader, slightly raised and finely tuberculate. Both the central and the anterior ridges are produced into spines, those from the former being considerably the longer. These spines curve backward and increase in length towards the posterior end of the body.

Tail broad, granulate. The axis consists of two rings and a terminal knob, the second ring being often very indistinct. The margin bears a row of radiating spines, namely:—2 larger spines connected with the axis by a rib; 4 smaller ones between these; and 4, or perhaps 5, outside each of the larger spines.

*Horizons and Localities.*—In the Jermyn Street Museum there are specimens of this species from Brownthwaite, Gale Garth, Casterton Low Fell, and Ravenstone Dale. The last three localities are referred to the Upper Coldwell Beds by Mr. Marr,<sup>1</sup> who also records the species from the same beds at Helm Knot. In the Woodwardian Museum there are specimens collected by Prof. Hughes from beds above the Nant Glyn Flags at Pont Lawnt in Denbighshire, which he believes to be on the same horizon as the beds of Casterton Low Fell.<sup>2</sup>

The specimen on which Salter is stated to have founded the species was brought from Casterton Low Fell, and is now in the Woodwardian Museum.

In the Jermyn Street Museum there is a specimen of *Acidaspis* which is stated to come from the Llandeilo Flags near Pencerrig

<sup>1</sup> Geol. Mag. 1892, p. 538.

<sup>2</sup> Proc. Chester Soc. Nat. Sci. & Lit. pt. iv. 1893, p. 154.

House, Bulth. So far as can be seen, and the specimen is nearly complete, it is indistinguishable from *A. Hughesi*; but it is difficult to believe that this species can occur so low down in the geological scale. Pencerrig lies close to the boundary between the Wenlock and Llandeilo Beds, and it is possible that the specimen may have been obtained from the former.

**ACIDASPIS ERINACEUS, Marr & Nicholson.**

1888. *Acidaspis erinaceus*, Marr & Nicholson, Quart. Journ. Geol. Soc. vol. xlv. p. 723, pl. xvi. figs. 11 & 12.

This species having been recently figured and described, the only point to which it is necessary to call attention here is that the original of Messrs. Marr and Nicholson's fig. 11 shows, somewhat indistinctly, the frontal border in front of the glabella. The free cheeks are lost in the specimens, and hence the form of the head, with the glabella apparently projecting in front, seems abnormal in the figure.

The species is compared by Marr and Nicholson with *A. centrina*, Dalm., from the same horizon in Sweden.

*Horizon and Locality.*—Llandovery Beds: in the *Acidaspis erinaceus*-zone of the Stockdale Shales at Torver Beck.

**ACIDASPIS CALLIPAREOS, Wyv. Thomson.**

1857. *Acidaspis callipareos*, Wyv. Thomson, Quart. Journ. Geol. Soc. vol. xiii. p. 208, pl. vi. figs. 11, 12; 1878. Nicholson & Etheridge, 'Mon. Sil. Foss. Girvan,' p. 125.

Only the head is described by Wyville Thomson; and it is believed by Nicholson and Etheridge to be probably the head of *A. hystrix*. The two, however, are stated to have been found on different horizons. Wyville Thomson considers *A. callipareos* to be very closely allied to *A. pectinata*, Ang.

*Horizon and Locality.*—According to Wyville Thomson, the specimens were found in the Mullock Hill Sandstone near Girvan. This is of Llandovery age.

Two other species, to which Fletcher and Salter<sup>1</sup> gave the names of *Acidaspis Dama* and *A. dumetosus*, are stated to occur in the 'Upper Silurian' at Dudley. No description of them has been published; and I have been unable to find, in the various collections arranged by Salter, any specimens ascribed to *A. dumetosus*. In the Jermyn Street Museum several fragments from various horizons are referred to *A. Dama*, but they are not sufficient to afford a sound basis for the description of the species. The specimens from the Wenlock Shale show a pair of spines springing from the neck-segment, and are clearly distinct from any of the forms here described.

<sup>1</sup> Morris, 'Catalogue of Brit. Fossils,' 2nd ed. (1854) p. 99.

III. COMPARISON WITH THE SWEDISH AND BOHEMIAN FAUNAS.<sup>1</sup>

If we compare the British Silurian species of *Acidaspis* with those from the same beds in Bohemia and Sweden, we arrive at some interesting results. The following table includes all the species which have yet been described from the Silurian of Sweden<sup>2</sup> and Britain, and also those from Bohemia which are nearly allied to any of the Swedish or British forms. There are, however, numerous Bohemian species besides these.

In the table the species which are closely allied to each other are placed upon the same horizontal line, so as to show the amount of resemblance between the three faunas:—

SWEDEN.	BRITAIN.	BOHEMIA.
<i>A. bicuspis</i> .*	<i>A. Brighti</i> .	<i>A. Grayi</i> .†
<i>A. crenata</i> ; <i>A. Barrandei</i> , Ang.	<i>A. Barrandei</i> , F. & S.	<i>A. vesiculosa</i> , etc.
<i>A. coronata</i> (= <i>A. Marklini</i> ).	<i>A. crenata</i> .	
<i>A. centrina</i> .	<i>A. coronata</i> .‡	
<i>A. pectinata</i> .	<i>A. erinaceus</i> .	
	<i>A. callipareos</i> .†	
	<i>A. deflexa</i> .	
	<i>A. quinquespinosa</i> .§	
	<i>A. Hughesi</i> .	
<i>A. cornuta</i> .†		Numerous other species.

\* Only a single fragment of *A. bicuspis* appears to have been discovered.

† I have had no opportunity of examining these species.

‡ *A. coronata* occurs in Germany, but only in the boulders of the Glacial deposits, and these have probably come from Sweden.

§ The specimen of *A. quinquespinosa* described by Beyrich under the name *A. Brightii* came, not from Bohemia, but from Ludlow.

So far, then, as this comparison goes, two species from the British Silurian are represented by closely allied forms in Bohemia, and five in Sweden. There is but one Swedish species represented in Bohemia, of which only a single specimen is known; and, on the other hand, there is only one which is not represented in Britain. Lastly, there are more species of *Acidaspis* in the Silurian of Bohemia than in the Silurian of Sweden and Britain put together.

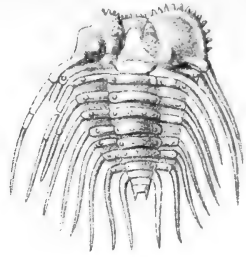
These results are suggestive, but they are no more. Until a larger number of species has been examined, it would be rash to draw

<sup>1</sup> I have to thank Prof. Lindström for permission to examine the magnificent series of trilobites in the Riksmuseum at Stockholm, and for much kind assistance during my stay in that city.

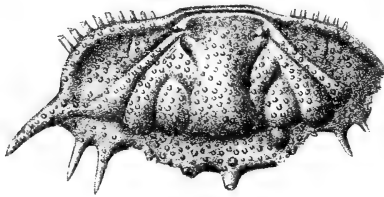
<sup>2</sup> See Prof. Lindström's 'List of the Fossil Faunas of Sweden,' edited by the Palæontological Department of the Swedish State Museum (Natural History), pts. i. & ii. Stockholm, 1888. The two species *A. centrina* and *A. cornuta* from the upper 'Brachiopod Schists' are included, since those beds seem to contain a certain number of Llandovery forms.



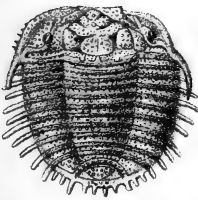
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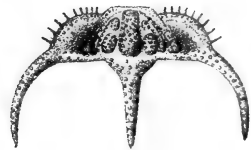
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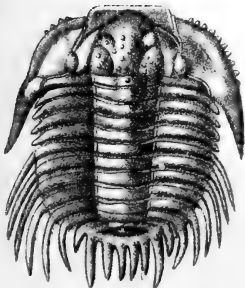
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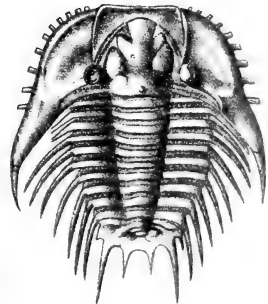
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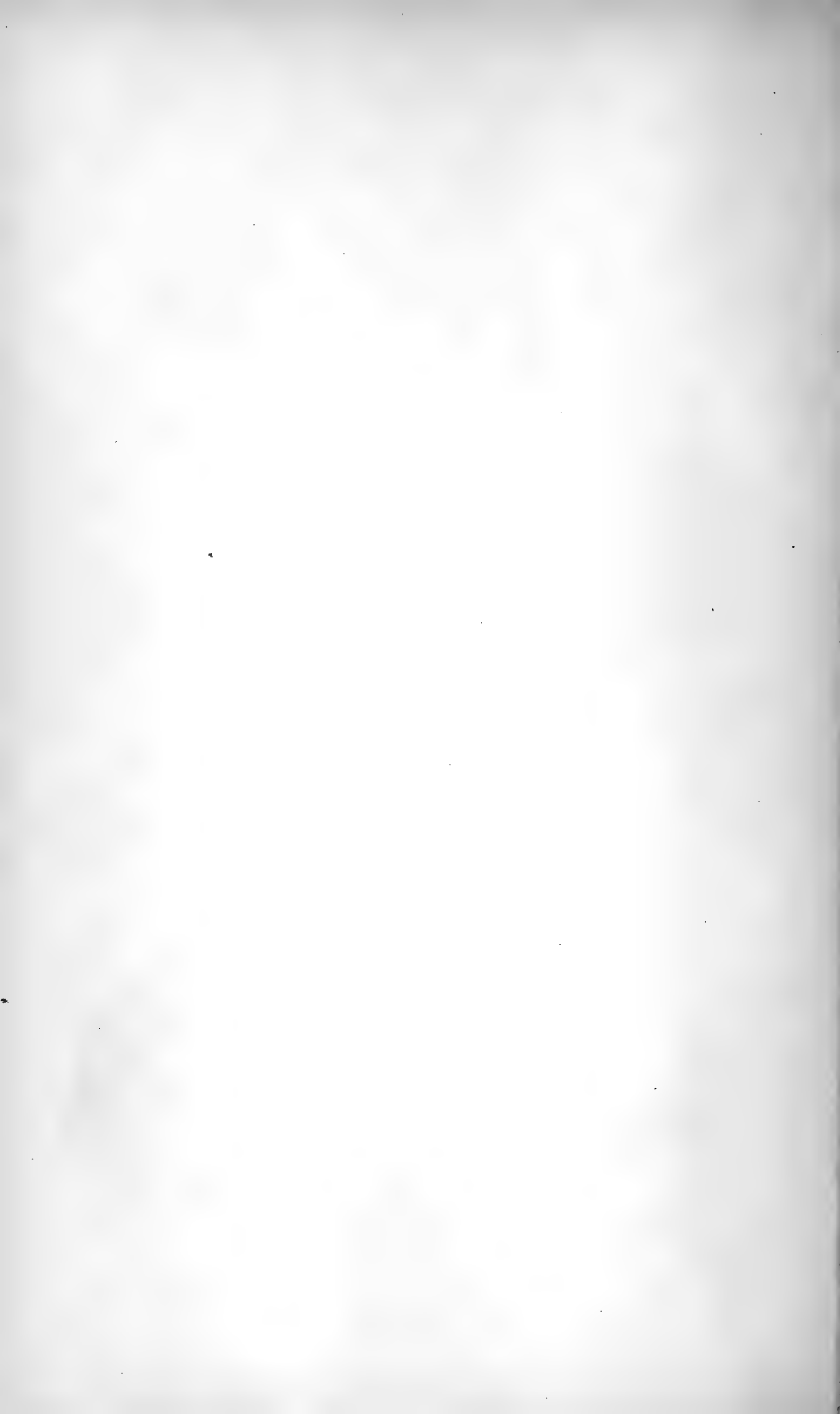
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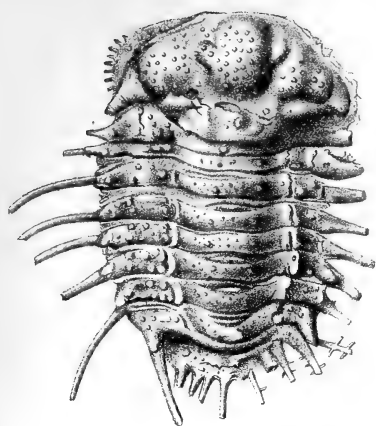


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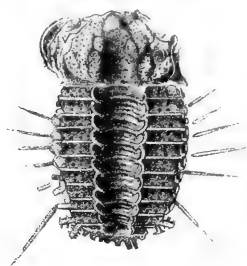
BRITISH ACIDASPIS

Edwin Wilson. Cambridge

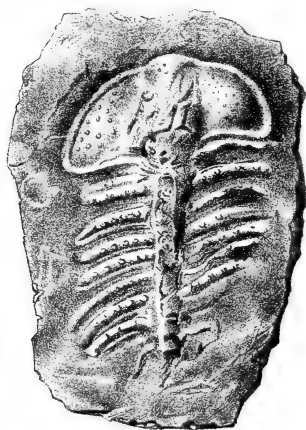




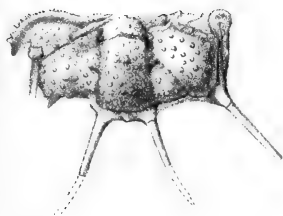
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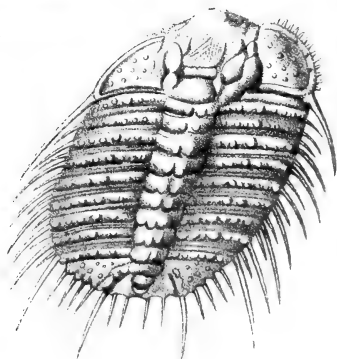
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BRITISH ACIDASPIS.

Edwin Wilson. Cambridge





any conclusions. So far, however, as the genus *Acidaspis* is concerned, it appears that the British Silurian fauna is intermediate between those of Sweden and Bohemia, but more closely allied to the former.

## EXPLANATION OF PLATES VII. &amp; VIII.

## PLATE VII.

- Figs. 1 & 2. *Acidaspis crenata*, Emm., sp. Wenlock Beds, Dudley. British Museum (Nat. Hist.). 1. Broad-tailed form,  $\times 2$ . 2. Narrow-tailed form,  $\times 2$ .  
 3 & 4. *A. quinquespina*, Salt. 3. Entire specimen, deprived of its test. Wenlock Limestone, Wren's Nest, Dudley. Brit. Mus. Nat. size. 4. Head, with test preserved. Wenlock Limestone, Dudley. Fletcher Collection, Woodwardian Museum.  $\times 2\frac{1}{2}$ .  
 Fig. 5. *A. Brighti*, Murch. Head. Wenlock Limestone, Dudley. Fletcher Coll., Woodw. Mus.  $\times 1\frac{1}{2}$ .  
 6. *A. coronata*, Salt. Wenlock Limestone, Dudley. Museum of Practical Geology, Jermyn Street.  $\times 2$ .  
 7. *A. deflexa*, sp. nov. Wenlock Shale, Dudley. Brit. Mus.  $\times 2$ .

## PLATE VIII.

- Figs. 1-3. *Acidaspis Barrandei*, Fletch. & Salt. Wenlock Limestone, Dudley. Fletcher Coll., Woodw. Mus. 1. The most complete specimen known; anterior and posterior segments partially concealed. Nat. size. 2. Specimen showing internal view, with all the thoracic segments displayed. Nat. size. 3. Head, showing occipital spines.  $\times 1\frac{1}{2}$ .  
 4, 5. *A. Hughesi*, Salt. 4. Salter's type. Casterton Low Fell. Woodw. Mus.  $\times 2$ . 5. S. of Gale Garth, Casterton. Mus. Pract. Geol.  $\times 2$ .

## DISCUSSION.

The PRESIDENT said that the Author was pursuing the only safe method possible at the present day when working at any special group, namely, to visit the Museums and localities abroad where such specimens are to be studied. Mr. Lake had already visited Sweden, and hoped to study the trilobites of Bohemia. His work would be very welcome to all palæontologists.

Mr. MARR remarked that the Bohemian beds lying between the Ordovician and Devonian were not very rich in trilobites, except those of Upper Ludlow age. He asked whether *Acidaspis erinaceus* was closely related to *A. centrina*, and whether the latter was considered identical with *A. granulata*. He was glad to find that *A. Hughesi* was at last described. Two entirely different species, one Silurian and one Devonian, had been named *A. Hughesi*, with the result that in future fossil lists *A. Hughesi* will probably be recorded as a form passing from Silurian to Devonian.

The AUTHOR replied that *Acidaspis granulata*, Ang., was generally looked upon by Swedish palæontologists as a synonym of *A. centrina*, Dalm.

12. *On the STRUCTURE of the PLESIOSAURIAN SKULL.* By CHARLES W. ANDREWS, Esq., B.Sc., F.G.S. (Read February 26th, 1896.)

[PLATE IX.]

THE structure of the skull of the Liassic Plesiosaurs has been discussed by many writers, but the various accounts that have been given of it are incomplete, and often differ one from the other in important particulars, doubtless owing to the fact that in most cases the specimens examined are much crushed, and are embedded in the matrix, so that only one aspect is visible. In the National Collection there is, however, a fine skull of *Plesiosaurus macrocephalus*, which has lately been almost completely cleared from the matrix, so that it exhibits both the upper and under surfaces; this specimen, though it has been subjected to a slight vertical compression which has caused some fractures and dislocations, gives a fairly clear idea of the general arrangement of the constituent bones, and, since it throws light on some obscure points, seemed worthy of the following brief notice. Certain other specimens, which are of assistance in some difficulties, will also be referred to.

In 1838 Owen<sup>1</sup> figured and described the upper and lateral regions of the skull of *P. macrocephalus*, and in 1881 Sollas<sup>2</sup> described under the name *P. brachycephalus* some portions of the head of a specimen probably referable to the same species. Neither of these writers had an opportunity of examining the palate, and it is this region, therefore, that is more particularly considered here; while, in the structure of the rest of the skull, only such points are noticed as seem to add to, or to be at variance with, the descriptions already published.

The specimen (Pl. IX.) under consideration is from the Lias of Lyme Regis, and was referred to *Plesiosaurus macrocephalus* by Mr. Lydekker.<sup>3</sup> The occipital surface is still somewhat obscured by adherent matrix, and has the anterior cervical vertebræ attached to it, although the atlas has been dislocated from its articulation with the occipital condyle.

The bones of the palate (Pl. IX. fig. 1), though somewhat displaced from their natural positions, are, with the exception of the transverse bone, fairly well preserved and distinct, so that their form and relations can easily be made out.

The basioccipital (*b.oc.*) bears the whole of the nearly hemispherical occipital condyle, and carries on either side a stout, outwardly-directed tuberosity, the truncated end of which looks outward. In the Plesiosaurs the whole of these tuberosities is formed by the basioccipital, but in most reptiles the basisphenoid enters into their composition.

<sup>1</sup> Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xxxvii. (1881) pl. xxiv. fig. 1.

<sup>3</sup> Cat. Foss. Rept. Brit. Mus. pt. ii. (1889) p. 268, no. 49202.

The palatal surface of the basisphenoid (*b.sph.*) rises abruptly from the basioccipital; it is slightly concave from side to side, and is sharply separated from the lateral surfaces, which make an angle of from  $100^{\circ}$  to  $120^{\circ}$  with it. The posterior portion of these lateral surfaces forms a facet, looking outward and downward, with which the pterygoid articulates. The basisphenoid seems to have been overlapped by a parasphenoid (*pas.*), but the hinder border of that bone is indistinguishable; anteriorly it expands into a thin, spearhead-shaped plate, the outer angles of which in the present specimen overlap the ventral surface of the pterygoids, and with them limit the posterior palatine foramina (*post.pal.vac.*),<sup>1</sup> which open between the *basis cranii* and the pterygoids, as in *Peloneustes*. In this latter, however, the parasphenoid is slightly overlapped on its ventral surface by the pterygoids; this difference in the relative position of the bones in the two genera may be due to displacement in the present specimen.

The pterygoids (*pt.*) are triradiate bones, like those of *Peloneustes*, but differ from them in not meeting in the median line over the basisphenoid, and remaining separated by the whole palatal width of that bone. Anteriorly they have been dislocated from their junctions with one another and the surrounding bones, but there can be no doubt that in their natural position they met anteriorly and, together with the parasphenoid, closed the palate in the middle line.

Their anterior rami are thin triangular plates, the apices of which meet the vomers, while their inner borders form a median suture with one another in front, and are overlapped by the parasphenoid behind. In the uncrushed skull their outer edges united with the palatines.

The lateral rami run outward opposite the anterior end of the posterior palatine foramina; their outer ends are much thickened and in the present specimen have been partly broken away. In the skull of *P. dolichodeirus* noticed below (fig. 1, p. 248), the outer ends of these lateral rami are joined to the maxillary region by a transverse bone (*trs.*), and the same is the case in *Peloneustes* and *Pliosaurus*.

In front the posterior rami are narrow bars of bone forming the outer border of the posterior palatine foramina. Behind these openings they widen a little, and bear on their inner side facets for articulation with the corresponding surfaces on the sides of the basisphenoid. Posteriorly they run outward and backward as thin vertical plates to the quadrates, which do not appear to send forward to meet them plates of bone such as are seen in *Sphenodon*.

The *columella cranii* (Pl. IX. fig. 4, col.) or epipterygoid is well

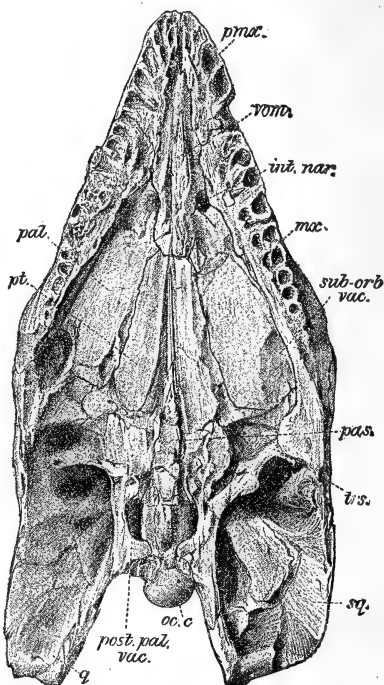
<sup>1</sup> In this paper, as well as in that on the skull of *Peloneustes* (Ann. Mag. Nat. Hist. ser. 6, vol. xvi. 1895, p. 242), the term 'post-palatine foramen' is used in a different sense from that in which it is sometimes employed (for example, by E. T. Newton in his papers on the Reptilia of the Elgin Sandstones), and is applied to the pair of foramina which result from the division of the median interpterygoid foramen by the basisphenoid and parasphenoid. Newton employs the term for the aperture which lies in front of the transpalatine, and is here called the 'suborbital foramen.'

shown in this specimen. It rises from the upper surface of the pterygoids about opposite their junction with the basisphenoid; its base of attachment is very long from before backward, so that it extends for a considerable distance along the upper edge of the quadrate process of the pterygoid. In its middle portion it contracts in width, and is an elongate oval in section. On both sides of the skull the upper portion of this bone has unfortunately been broken away, so that the junction with the parietals is not clear, but it evidently joined their lower edge at about their middle point.

The palatines (*pal.*) are elongated plates of bone, of which the anterior edges form the hinder margin of the nares; on the inner side they unite in front with the vomers, and behind with the pterygoids, while on the outer they join the maxillæ. In the present specimen the relations of the hinder border of the palatine are not clear, though it is evident that internally it joined the lateral ramus of the pterygoids; but in a skull of *P. dolichodeirus* (B.M. Coll. 41101) it can be seen (fig. 1) that externally the hinder border of the palatine joined the transpalatine for a short distance, and was then separated from it by a small suborbital foramen (*sub-orb. vac.*) which appears to be closed on its outer side by the maxilla. Mr. Lydekker<sup>1</sup> first called attention to these foramina in this specimen (fig. 1), in which also he first observed the fact that the pterygoids extend forward to meet the vomers.

The vomers (*vom.*) are not well preserved; they are long narrow bones which unite, and perhaps anchylose, in the middle line. Posteriorly they join the pterygoids, and in front of these, the palatines. About the middle of their length they form the division between the internal nares, and anterior to these apertures they run forward between the maxillæ and premaxillæ.

Fig. 1.—Palatal surface of the Skull of *Plesiosaurus dolichodeirus*. (About  $\frac{1}{2}$  natural size.)



<sup>1</sup> Cat. Foss. Rept. Brit. Mus. pt. ii. (1889) p. 257, no. 41101.

The lower surface of the maxillæ and premaxillæ is largely concealed by the mandible, which is tightly closed upon them. The inner border of the palatal plate of the maxilla is, however, visible for some distance both in front of and behind the internal nares, the outer border of which it forms. In its anterior region there are one or two pits which probably mark the points of eruption of successional teeth. The palatal portion of the premaxillæ is almost completely concealed by the symphyseal region of the mandible; but the anterior ends of the vomers appear to run forward some distance between these bones; in the above-mentioned skull of *P. dolichodeirus* this is certainly the case (fig. 1, p. 248).

The general structure of the Plesiosaurian palate is shown diagrammatically in fig. 2 (p. 251).

The structure of the temporal arcade (Pl. IX. fig. 3) is, in all essential respects, similar to that in *Plesiosaurus brachycephalus* (figured by Sollas),<sup>1</sup> *P. dolichodeirus*, and *P. Hawkinsi* (figured by Owen),<sup>2</sup> and also to that of *Peloneustes*:<sup>3</sup> the only important difference being that in the present species the postorbital sends back a long thin strip along the anterior ramus of the squamosal nearly to its origin. The supra-jugal which Sollas observed in *P. brachycephalus* cannot be detected, but, if I understand the description of that bone (it is not figured), it corresponds to the lower portion of the postorbital. The thin posterior extension of the maxilla along the lower edge of the jugal is concealed by the mandible, the pressure of which has driven it inwards.

The wall of bone described by Sollas, which separates the orbit from the temporal fossa, is well shown in this specimen. It appears to be mainly formed by the postfrontal and postorbital, each of which thus consists of an external facial and an internal postorbital portion, which meet in the angle forming the anterior rim of the temporal fossa. I cannot make out what share in the formation of this postorbital wall is taken by the jugal; according to Sollas it is an important one.

The upper ramus of the triradiate 'squamosal' is in this specimen indistinguishably fused with the remainder of that bone; but in the younger skull described by Owen it is separated by a distinct suture, which is figured by him.<sup>4</sup> He calls this upper portion the 'mastoid,' while the remainder of the bone, consisting of the inferior and anterior rami, is designated the 'squamosal.' It is clear that these two elements are equivalent to the supra-temporal and squamosal of lizards, according to the terminology of Parker & Bettany and many other writers, or to the squamosal and prosquamosal, according to Baur. Their arrangement is similar to that occurring in the Rhynchocephalia, the fused elements of the older individuals having almost exactly the form and relations of the so-called 'squamosal'

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxvii. (1881) pl. xxiv. fig. 2.

<sup>2</sup> Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.

<sup>3</sup> Ann. Mag. Nat. Hist. ser. 6, vol. xvi. (1895) p. 251, fig. 2.

<sup>4</sup> Trans. Geol. Soc. ser. 2, vol. v. pt. iii. (1840) pl. xlv.

of *Sphenodon*. Koken<sup>1</sup> has expressed the same opinion as to the constitution of the 'squamosal' in the Nothosauria. In several Plesiosaurian skulls in the British Museum the suture between these elements is distinct.

The quadrate (*q.*) is a long, stout bone; posteriorly it is convex from side to side, anteriorly concave. It projects downward and backward, and the condyle for the mandible lies somewhat below the level of the alveolar border of the maxilla. On its outer side the inferior ramus of the squamosal is closely adherent to it, and extends nearly down to the condyle.

In *Cimoliosaurus* Cope<sup>2</sup> has figured a small quadrato-jugal, and Koken<sup>3</sup> has recorded the probable occurrence of this bone in *Nothosaurus*; it therefore seems possible that the Plesiosaurian quadrate may be a fusion of the quadrate and quadrato-jugal, a view which derives some support from the fact that the relations of the squamosal to the 'quadrate' are almost exactly similar to those existing between the squamosal and the quadrato-jugal in *Sphenodon*.

The general structure of the upper surface of the skull is shown in Pl. IX. fig. 2. It will be seen that between the anterior halves of the temporal fossæ the parietals form a high, sharp crest, but that posteriorly they widen out into a broad triangular plate, convex from side to side, which apparently roofs in the brain-case. The outer angles of this plate are overlapped by the upper rami of the squamosals, these forming the hinder border of the temporal fossæ. In front, opposite the anterior end of these fossæ, the parietals enclose the pineal foramen, which does not extend into the frontals, and laterally they widen out and take part in the formation of the postorbital wall. There is clearly a distinct post-temporal fossa, closed above by the lateral process of the parietal and the upper ramus of the squamosal. The frontals extend much farther forward than in *Peloneustes*, and separate the external nares. I can find no clear evidence of the existence of distinct nasals and lacrymals.

Comparison of the palatal portion of this skull with that of *Peloneustes* shows that the chief difference between them is that in the latter the pterygoids, instead of merely articulating with the sides of the basisphenoid, overlap it, and form a median suture with one another on its ventral surface. In *Peloneustes*, also, the form of the parasphenoid is different, and it is very uncertain whether there is any suborbital vacuity.

In *Nothosaurus* the pterygoids meet in the middle line from end to end, and there is no suborbital vacuity, so that the palate is completely closed; this appears to be a more specialized condition than occurs in either *Plesiosaurus* or *Peloneustes*, although both these genera are of a later date.

<sup>1</sup> 'Beiträge zur Kenntniss der Gattung *Nothosaurus*,' Zeitschr. deutsch. geol. Gesellsch. vol. xlv. (1893) p. 363.

<sup>2</sup> 'On the Structure of the Skull in the Plesiosaurian Reptilia,' Proc. Amer. Phil. Soc. Philadelphia, vol. xxxiii. (1894) p. 110.

<sup>3</sup> *Op. supra cit.*

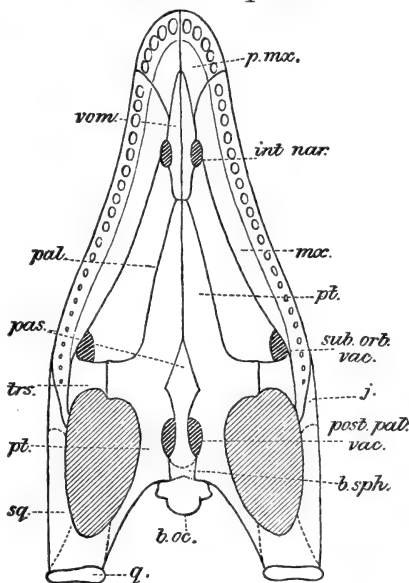
In *Lariosaurus*<sup>1</sup> the palate is essentially similar to that of *Plesiosaurus*, but here again the pterygoids completely shut in the *basis cranii*. The suborbital vacuity is very large, and the pterygoids bear teeth, both probably primitive characters. The palate of *Neusticosaurus* is doubtless similarly constructed, but the suborbital vacuities are still larger.

In *Pistosaurus* the pterygoids appear to leave the *basis cranii* exposed for some distance, and in this respect the palate in this genus is more Plesiosaurian in form than is that of any other Triassic Sauropterygian.

Among reptiles other than the Sauropterygia the palate most similar to that under consideration is found in *Sphenodon*. In this reptile the form and the relations of the bones of the palate to one another and to the internal nares are almost identical with those above described. The only difference of importance is that the pterygoids, instead of articulating directly with the sides of the basisphenoid, are borne off from it by downwardly-directed basi-ptyergoid processes, so that they come to lie at a lower level than the *basis cranii*. The consequence of this arrangement is that the parasphenoid, here very small, does not run forward between them dividing the interptyergoid vacuity into two post-palatine foramina.

Too much importance must not be attached to the similarity existing between the palates of these two forms, since the Rhynchocephalian type of palatal structure occurs in a more or less modified form in many widely divergent reptilian groups, and probably therefore approaches the primitive type of structure common to the ancestors of those various groups. For instance, the Ichthyosaurian palate, except that the lateral wing of the pterygoid is reduced, and the transverse bone consequently absent, is very like that of *Sphenodon*. Again, among the Anomodonts, *Procolophon* is, so far as the palate is concerned, Rhynchocephalian; the presence of teeth

Fig. 2.—Diagrammatic figure of the *Plesiosaurian* palate.



<sup>1</sup> For my knowledge of the structure of the palate in this genus I am indebted to Mr. Boulenger, who kindly allowed me to see a proof of his forthcoming paper on the skeleton of *Lariosaurus Balsami*.

on its pterygoids and vomers is probably a primitive character derived from its Labyrinthodont ancestors; the palate of *Pareiasaurus* is similar.

In the Theriodonts a short secondary hard palate is developed, carrying back the opening of the internal nares; but in some specimens (for example, the skull of *Galesaurus planiceps*, B.M. R. 511) the relations of the bones constituting the primitive palate are *Sphenodon*-like, the pterygoids extending forward to meet the vomers, and their lateral rami bearing a downwardly-directed process (ectopterygoid) which lies against the inner side of the closed mandible, and is no doubt partly formed by a transpalatine element. There seems to be no suborbital vacuity.

The palatal structures of the Chelonians, regarded as modifications of the same type, are easily comprehensible, and the same is the case with the Lacertilia. In the highly specialized palate of the Crocodilia, the resemblance to the primitive form is masked by the secondary hard palate formed by the palatines and pterygoids; but if this be disregarded, the same type of structure may be traced here also.

Enough has been said to show that among reptiles a certain similarity of palatal structure does not necessarily imply any close relationship, but the very great resemblances existing between the Plesiosaurian and Rhynchocephalian palates, reinforced by the numerous other points of likeness in other portions of their skeletons pointed out by Baur, lead to the conclusion that the Sauropterygia, notwithstanding their single temporal arcade and thecodont dentition, are descended from a primitive Rhynchocephalian reptile. This opinion has already been expressed by several writers, notably by Baur<sup>1</sup> and Boulenger.<sup>2</sup>

#### EXPLANATION OF PLATE IX.

Skull of *Plesiosaurus macrocephalus*, Buckland.

Fig. 1. From below.

2. From above.

3. From the side.

4. Temporal fossa seen obliquely from the side, showing the relations of the *columella*.

*ang.*, angular.  
*b.oc.*, basioccipital.  
*b.sph.*, basisphenoid.  
*col.*, columella cranii.  
*ext.nar.*, external nares.  
*int.nar.*, internal nares.  
*fr.*, frontal.  
*jug.*, jugal.  
*mx.*, maxilla.  
*orb.*, orbit.  
*pal.*, palatine.  
*par.*, parietal.

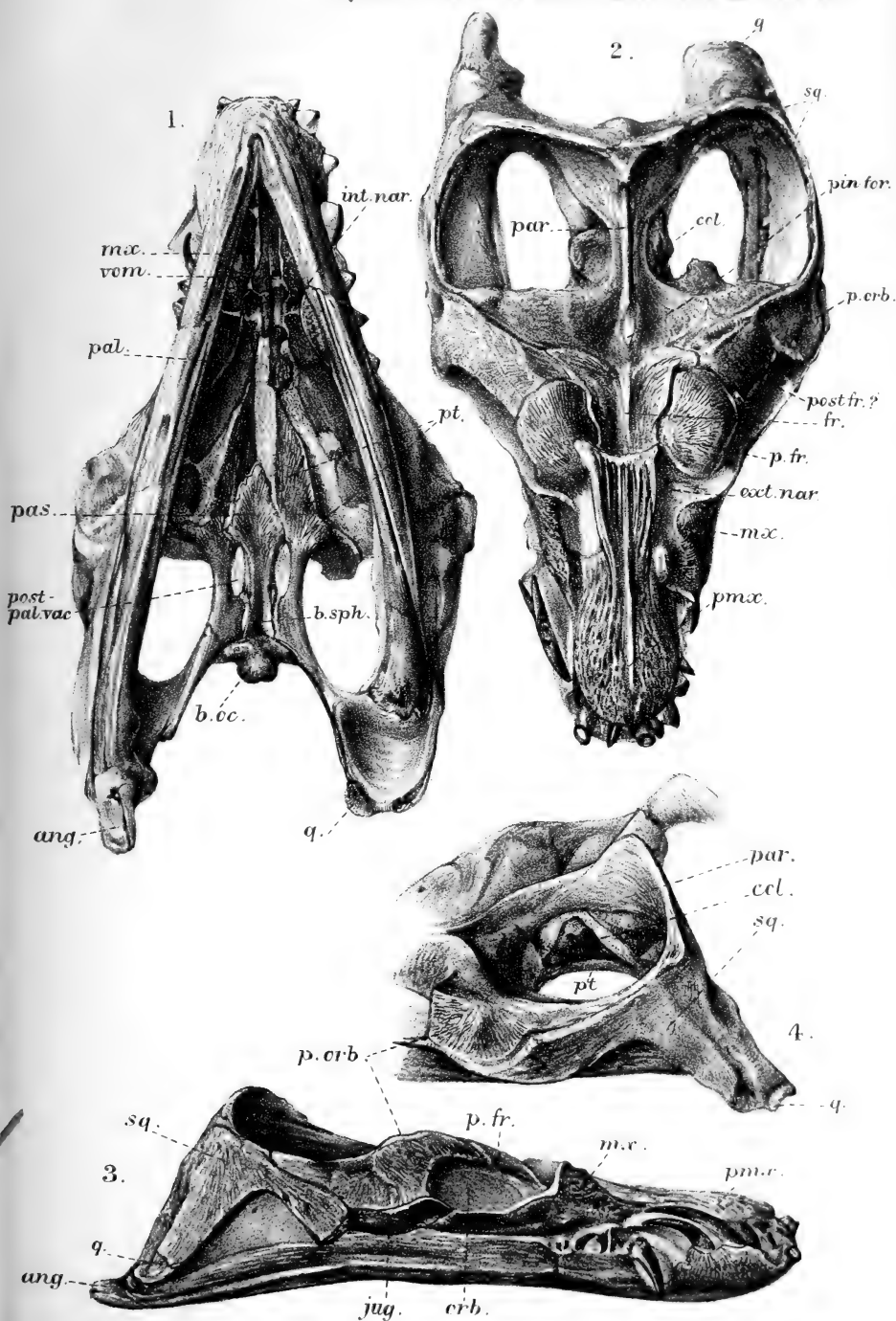
*pas.*, parasphenoid.  
*pin.for.*, pineal foramen  
[misprinted *pm.for.*].  
*pmx.*, premaxilla.  
*p.orb.*, post-orbital.  
*p.fr.*, pre-frontal.  
*? post.fr.*, ? separate post-frontal.  
*post.pal.vac.*, posterior palatine  
vacuities.  
*q.*, quadrate.  
*sq.*, squamosal.  
*vom.*, vomer.

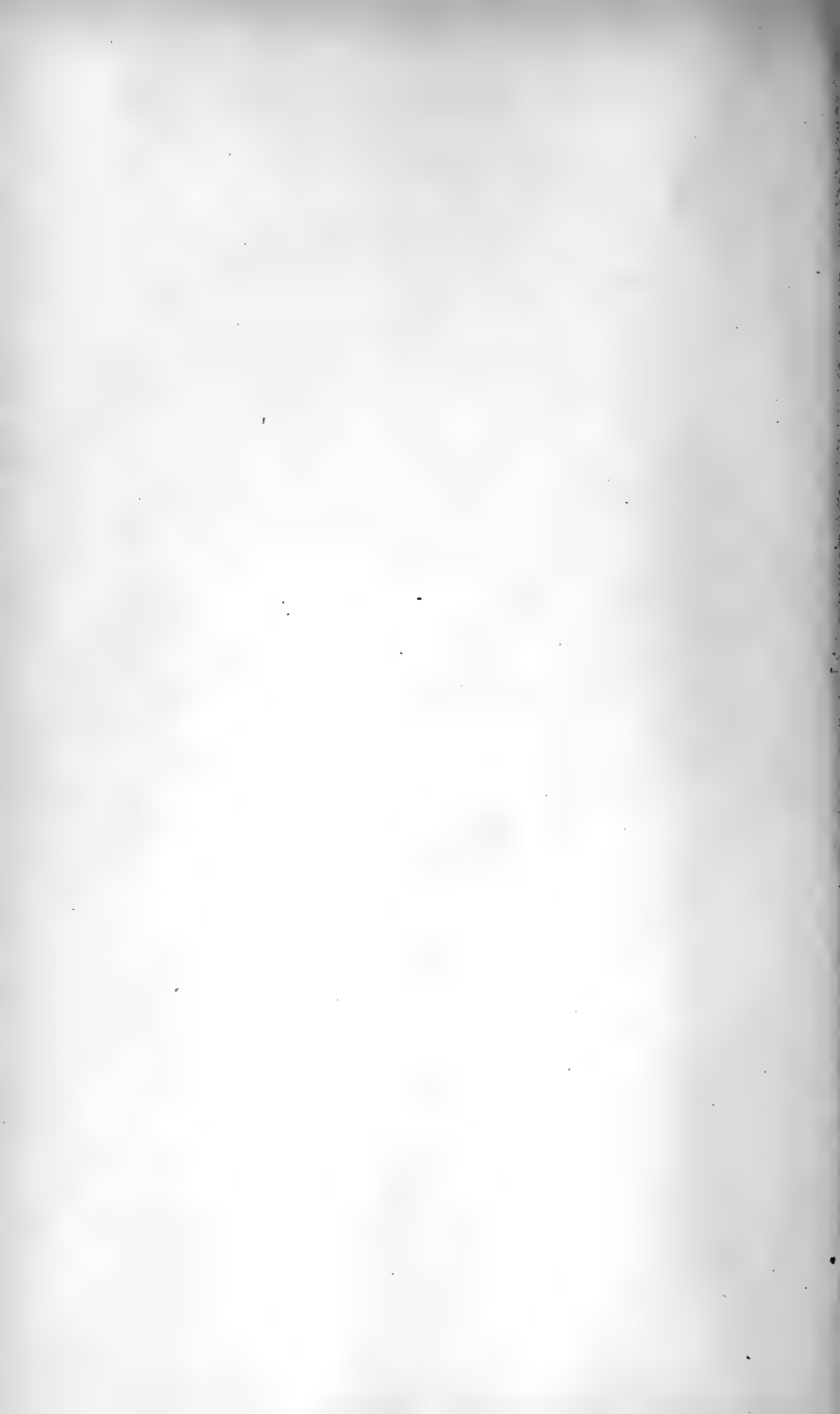
All the figures are about  $\frac{1}{2}$  natural size.

<sup>1</sup> 'On the Phylogenetic Arrangement of the Sauropsida,' Journ. Morph. vol. i. p. 93.

<sup>2</sup> Cat. Chelonians, Rhynchocephalians, and Emydosaurians in the British Museum, p. 1.







## DISCUSSION.

The PRESIDENT invited discussion.

Prof. HOWES, on behalf of morphologists, gave expression of gratitude to the Trustees and Staff of the British Museum of Natural History for the work now being accomplished in their Geological Department. He remarked that he had been privileged to examine the Author's specimens, and that he fully confirmed his determinations. He could not accept the idea, to which reference had been made, that *Pareiasaurus* had a closed palate in the ordinary sense; that is to say, the internal nasal openings were not carried to the back of the palate by the union of the palato-pterygoid bones as they are in the Crocodilia.

In concluding, he pointed out that the Author's determinations of the bony palate of the Sauropterygia were in complete harmony with Mr. Lydekker's of that of the Ichthyopterygia, and with the best-established facts of morphology; and that, thanks to these gentlemen, we were now in a position to definitely refer the 'Enaliosauria' to an origin among the lowest reptiles.

Mr. LYDEKKER and Dr. WOODWARD also spoke.

The AUTHOR expressed his thanks to the Fellows, particularly those who had spoken, for the kind manner in which they had received his paper. He also referred to his indebtedness to Mr. Hall, one of the 'masons' at the Natural History Museum, for the skilful way in which he had cleared the specimen from its hard matrix.

13. *On the MORTE SLATES, and ASSOCIATED BEDS, in NORTH DEVON and WEST SOMERSET.*—Part I. By HENRY HICKS, M.D., F.R.S., P.G.S. (Read February 5th, 1896.)

## [PLATES X. &amp; XI.]

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## I. INTRODUCTION.

HITHERTO the Morte Slates have received but scant attention from geologists, owing to the fact that in all text-books, and in geological papers on North Devon, they have always been referred to as unfossiliferous; and all that was known with regard to them up to the year 1887 is well summarized in the following paragraph taken from the second edition of Mr. H. B. Woodward's well-known work, 'The Geology of England and Wales,' p. 127:—'This division, termed the Morte Slates by the Rev. D. Williams, derives its name from Morte Point, on the north-west coast of Devon. The term Morte-hoe Group, from the village of that name, was used by John Phillips. The Morte Slates, or "grey slates," comprise pale greenish-grey and silvery grey glossy slates, much veined with quartz, and having a thickness estimated at from 3000 to 4000 feet. No fossils have been found; nor have any limestone-bands been recognized in them. The beds rest on the Ilfracombe Beds at Lee Bay, and the subdivisions which can be traced are noted by Mr. Etheridge (in ascending order) as the Lee, Rockham Bay, and Morthoe Beds. The Morte Slates pass downwards into the Ilfracombe Beds, and in Mr. Ussher's opinion they are simply an upper unfossiliferous portion of this lower division, since it is impossible to fix any definite boundary between them. Simonsbath is situated in the valley of the Barle, between the Ilfracombe and Morte Beds. Eastwards they extend to near Wiveliscombe, where they are exposed at the Oakhampton Slate quarry, north of that town. The slaty beds of Hestercombe, north of Taunton, are probably on the horizon of the Morte Slates. The valuable spathose iron-ore of the Brendon Hills occurs in these beds.'

On November 26th, 1890, I read a paper before this Society 'On the Rocks of North Devon,' in which I stated that during a recent visit to North Devon not only had I found that the Morte Slates were fossiliferous, but that I had come to the conclusion that they were the oldest rocks in the area, and that they had, as the result of movements in the earth's crust, been brought to the surface and thrust over much newer rocks, producing a deceptive appearance of overlying the latter conformably.

As my views regarding the succession were strongly controverted at the time, the paper was withdrawn, and I decided to re-examine the area, and to carry my researches into other districts which I had not previously had an opportunity of visiting. As this has necessitated the spending of several weeks each year, since the paper was read, either in North Devon or West Somerset, much additional evidence bearing on the succession has been obtained; but in this that relating mainly to the position and age of the Morte Slates will be referred to.

The beds included under the term 'Morte Slates' are for the most part much folded and highly cleaved, and the fossils are in consequence frequently much distorted and in a bad state of preservation. A considerable amount of labour and time has therefore had to be expended on these rocks to obtain anything like a satisfactory fauna. The results on the whole, however (when it is remembered that up to 1890 these beds were always referred to as unfossiliferous), must be considered as highly important, since we are now able by the aid of the fossils to define the age of a very considerable portion, if not of the whole, of these beds. That they must necessarily furnish the clue by which the succession in North Devon is to be unravelled will, I think, be generally admitted. Therefore, if their geological horizon can be settled the main difficulties which have so long surrounded the 'Devonian question' in North Devon, and which have led to so much controversy in the past, will virtually disappear.

In the geological map given in Mr. Etheridge's very important paper published in this Journal in 1867, the Morte Slates are shown as extending continuously from Morte Point to near Wiveliscombe, in West Somerset, a distance of over 40 miles. That rocks which possess characters resembling in many ways the typical Morte Slates are to be found all along this line there can be no doubt, but it will be shown that, here and there, they vary much in appearance and belong to different geological horizons. The strike of the beds also changes, and is seldom quite parallel with the overlying strata.

In my search for fossils in these rocks I have received invaluable assistance from my friends the Rev. G. F. Whidborne, M.A., F.G.S., and Mr. J. G. Hamling, F.G.S., of Barnstaple. I have also to express my indebtedness for special assistance with regard to some of the fossils from Mr. Sharman and Mr. Allen, of the Museum of Practical Geology; Mr. Bather, of the British Museum (Natural

History); Mr. F. Cowper Reed, of Cambridge; Mr. J. Hopkinson, and Prof. C. Lapworth.<sup>1</sup>

<sup>1</sup> [A complete *résumé* of the literature of the North Devon rocks up to the year 1867 has been given by Mr. Etheridge in his paper already referred to. Up to the year 1868 the views put forward by Sedgwick, Murchison, Godwin-Austen, De la Beche, and Phillips received general acceptance, but during that and subsequent years Prof. Jukes suggested modifications which tended towards a very different interpretation. In his paper in the Quart. Journ. Geol. Soc. in 1866, vol. xxii., he says at p. 321: 'As I shall have to maintain that all the first geologists of the day, including Prof. Sedgwick, Sir R. I. Murchison, Mr. Weaver, Sir H. De la Beche, and Prof. Phillips, have misunderstood the structure of the country, let me hasten to avow my belief that nobody whose observations were confined to Devon and Somerset could have arrived at any other than their conclusions. I fully admit that the rocks near Lynton appear to be the lowest, and that there appears to be a regular ascending succession of rock-groups from Lynton to the latitude of Barnstaple. I am, however, compelled to dispute the reality of this apparent order of succession, and to suppose that there is either a concealed anticlinal with an inversion to the north, or, what I believe to be much more probable, a concealed fault running nearly east and west through the centre of North Devon, with a large downthrow to the north, and that the Lynton beds are on the same general horizon as those of Baggy Point and Marwood.'

In 1867 Mr. Townshend M. Hall, whose researches have added so much to our knowledge of the North Devon rocks and their fossil contents (Quart. Journ. Geol. Soc. vol. xxiii. p. 371), subdivides the North Devon series, in ascending order, as follows:—Foreland group, Lynton zone, Martinhoe beds, Ilfracombe group, Morthoe group, *Cucullæa*-zone, Pilton beds—and says: 'From the Foreland on the north to Barnstaple on the south the rocks have an almost uniform dip to the south, usually at a high angle, presenting to all appearance an unbroken succession.'

Mr. Etheridge, in his paper of the same year (*op. cit.* vol. xxiii. p. 568), strongly controverts the views put forward by Prof. Jukes, and maintains that the succession in North Devon is one unbroken and continuous series. He subdivides the rocks in ascending order as follows (p. 580):—

Lower Devonian.	{	<i>a.</i> Lynton Sandstone. (Foreland Beds.) <i>b.</i> Lynton Slates.
Middle Devonian.	{	<i>c.</i> Hangman Grits. <i>d.</i> Calcareous Slates (fossiliferous). (Ilfracombe Beds.) <i>e.</i> Grey unfossiliferous slates. (Morte Slates.)
Upper Devonian.	{	<i>f.</i> Pickwell Down Sandstones. <i>g.</i> Baggy and Marwood Slates, etc. <i>h.</i> Croydon [Croyde] Beds. <i>i.</i> Braunton Beds. <i>k.</i> Pilton and Barnstaple Beds.

He further says at p. 694: 'After very careful investigation into the physical structure of North Devon, as well as a critical examination of the organic remains contained in its diversified rock-masses, I can come to no other conclusion than that the series of sandstones, slates, and limestones ranging from the Foreland and Lynton on the north to Pilton and Barnstaple on the south are one great and well-defined system, and equally well divisible into three groups, a Lower, Middle, and Upper Devonian series, each equally well characterized by a fauna, the zoological facies of which are sufficiently distinct to determine them one from the other.'

The following appears to be the final arrangement suggested by Prof. Jukes; it occurs in a paper read before the Royal Geological Society of Ireland in

## II. MORTHOE AND WOOLACOMBE TO BITTADON.

The beds are well exposed at Morte Point and in the cliffs of Rockham Bay on the northern side, and between the Point and Woolacombe on the southern side. At the Point the beds are nearly vertical, being folded so acutely that the bedding, owing to the cleavage, is with difficulty made out. Under Morthoe, however, there are some well-marked folds, and the strike is shown to be from about W.S.W. to E.N.E. The folds are here, as in most places along this

November 1867, and is given in reply to the papers in the Quart. Journ. Geol. Soc. of that year by Mr. Townshend Hall and Mr. Etheridge.

## Southern Area.

5. Pilton and Barnstaple Beds.
4. Braunton Beds.
3. Croyde Beds.
2. Baggy and Marwood Slates.
1. Pickwell Down Sandstones (red).

## Northern Area.

5. Grey unfossiliferous slate. (Morte.)
4. Calcareous Slates. (Ilfracombe.)
3. Hangman Grits.
2. Lynton Slates.
1. Lynton Sandstone (red).

Prof. Jukes places the beds, as named by Mr. Etheridge, in parallel columns, with the view of showing that the groups in the one area are merely a repetition of those in the other.

Since that time the rocks have been investigated by Messrs. Valpy, Hall, Champernowne, Usher, and others; but no important change in the classification suggested by Mr. Townshend Hall and Mr. Etheridge has been attempted by them. In a paper on the 'History of the Classification and Nomenclature of the North Devon Rocks,' in the Trans. Devonshire Assoc. 1879, p. 189, Mr. Townshend Hall says: 'On the whole, as far as North Devon proper is concerned, I believe the following classification is the best that can be adopted for the Devonian beds:—

Upper Devonian.	{ Pilton Beds. Cucullæa-zone (Baggy Point, etc.). Pickwell Down Sandstone.
Middle Devonian.	{ Morthoe Slates. Ilfracombe Slates and Limestones. Martinhoe or Hangman Grits.
Lower Devonian.	{ Lynton Beds. Foreland Sandstones.

And at p. 190, he says:—'It will be found that the North Devon Beds from Lynton to Pilton, though possessing a general dip to the south, are folded into many anticlinals, reducing their apparent thickness very considerably. I know this to be the case at so many different places throughout the area that, until we have a re-survey on the six-inch scale, I fear it will be a hopeless task to attempt to map the exact boundaries of the subdivisions, or to estimate their real thickness.'

In Sir H. De la Beche's 'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839, a section across the North Devon Beds is given (fig. 1, pl. iii.) which shows several main folds; and Dr. Sorby, in his well-known paper 'On the Origin of Slaty Cleavage' (Edinb. New Phil. Journ. vol. iv. 1853, p. 137), and Mr. J. E. Marr, in his important paper 'On some Effects of Pressure on the Devonian Sedimentary Rocks of North Devon' (Geol. Mag. 1888, p. 218), have shown how the rocks in places have been greatly affected and minutely folded and broken by pressure. See also Jukes, Quart. Journ. Geol. Soc. vol. xxii. (1866) p. 371; Champernowne, Geol. Mag. 1878, p. 193; Champernowne & Usher, Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 532 and Hicks, Geol. Mag. 1893, p. 3.—April 15th, 1896.]

coast, much broken, and the beds near the lines of fractures much seamed with quartz-veins. All the beds are strongly cleaved, and the cleavage-planes are either vertical or with a slight inclination towards the south. There are, here and there, a few thin sandstone-bands, but the majority of the rocks are hard, cleaved slates, and flags of a greyish colour. Where the hard bands occur they are usually much broken by the cleavage, and the broken fragments frequently give to the rocks quite a nodular appearance.

The slates dipping at a high angle can be traced as far south as the Lifeboat House, and also in the bed of the stream at the foot of Challacombe Hill, to a height of about 100 feet. Above this the ground rises rapidly, and a quarry which has been opened for building-stone at a height of about 230 feet, and distant from the last exposure of Morte Beds about 500 feet, shows massive purple, red, and grey grits and sandstones folded and much broken. These, and an exposure close by on Potter's Hill, are the lowest of the Pickwell Down Beds found on the coast, and as they are strongly ripple-marked they must have been deposited in shallow water. Still, their broken condition would indicate a faulted junction at this point. In the quarry one dip is to S.S.E., another to S.S.W., and on Potter's Hill to S.S.E. at 40°. The Pickwell Down Beds extend in an easterly direction, and may be again examined in several quarries on the high ground between here and the Foxhunter's Inn, on the road from Ilfracombe to Barnstaple. Opposite the inn, on the western side of the railway, there is a large quarry, where very massive beds of sandstone are bent into gentle folds, and on the northern side crushed and broken as if near a fault.

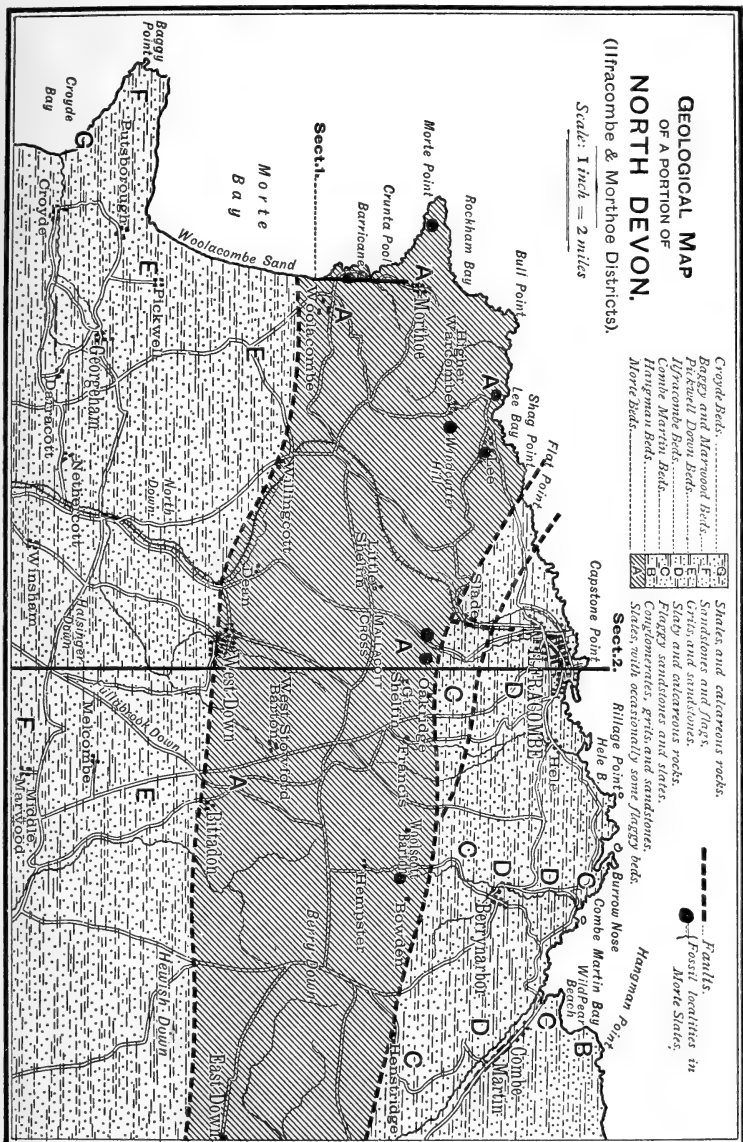
The Morte Slates are well exposed in the railway-cutting at Willingcott Bridge, and also at Deau, which is about  $\frac{1}{4}$  mile north of the Foxhunter's Inn. At the latter place they dip northward at about 70°, and differ somewhat in appearance from those exposed at Woolacombe, because a large number of hard bands of a fine-grained sandstone are interstratified with the slates. In following the junction between the Morte Slates and the Pickwell Down Beds up to this point, I could come to no other conclusion than that a fault separated them, and that as a consequence the same beds were very seldom in contact. Beyond West Down, and at Bittadon, the indications of an important fault between the Morte Slates and the Pickwell Down Beds are less marked, and the latter dip to the south at as low an angle as 15° near the inn at Bittadon. I searched carefully at and about Bittadon for evidences of a passage, but everywhere there appeared to be a sudden change from highly-cleaved slates, dipping at a high angle, to massive sandstone-beds with a low dip. It is a marked characteristic of the Morte Series that they are mainly hard, slaty, and flaggy beds made from fine muds, and that the few sandstone-beds are composed of well-rounded grains of quartz in an argillaceous matrix. When compared with the overlying rocks, the almost entire absence of mica is somewhat striking.

The Pickwell Down Beds which, in this area, immediately succeed



**GEOLOGICAL MAP**  
OF A PORTION OF  
**NORTH DEVON.**  
(Ilfracombe & Morthoe Districts).

Scale: 1 inch = 2 miles



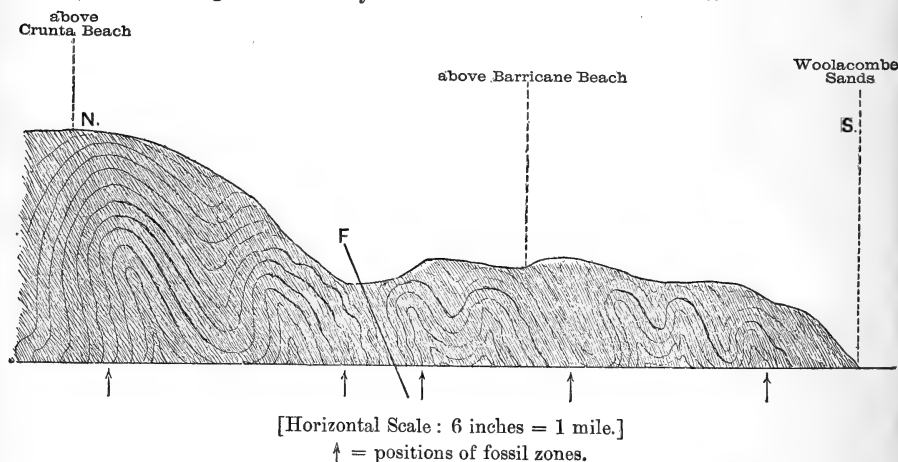
*Note.*—For 'Mallacott' read 'Mullacott'.

the Morte Slates, are characterized by containing angular bits of slate, angular and subangular quartz often stained of a red or chocolate colour, and frequently a considerable amount of a fresh-looking felspar. The sandstones and shales also contain an unusual proportion of detrital mica. When it is remembered that these beds often yield fossil wood, and are frequently ripple-marked, it becomes clear that they were deposited under different conditions from those which prevailed when the majority of the Morte Slates were thrown down, and the evidence certainly points to an important physical change taking place at no great distance about this time.

I have not met with any contemporaneous igneous rocks in the Morte Series, but there are a few intrusive dykes, one of the most important being the felsite at Bittadon described by Prof. Bonney.<sup>1</sup> Others have been referred to by Mr. Etheridge and Mr. Townshend Hall in Morte Bay, Lee Bay, etc.

The Morte Slates in this area yield traces of fossils in many places, but none sufficiently well-preserved for identification, excepting in the cliff-sections at Morthoe and Woolacombe. The first fossil found by me was a *Lingula* at Woolacombe in 1890; but since then several additional genera have been discovered at

Fig. 1.—Section from near Morthoe to Woolacombe.



Barricane, and in the cliffs at a small creek between Barricane and Crunta Point. They include a *Rhynchonella*, so like *Rh. Lewisii* of the Wenlock rocks that I have no doubt of its being the same species; a small *Spirifer* with a very wide mesial fold and somewhat rough ribs, unlike any British species known to me; and *Orthis rustica*, *Modiolopsis*, encrinites, etc.

<sup>1</sup> Geol. Mag. 1878, p. 207.

At Morte Point, in addition to some large *Lingulæ*, the slates were found to be covered with minute individuals of the same genus, but, as their structure was completely obliterated, very little could be made out of them. In the section (fig. 1) I have marked the positions of the fossil zones, and the folds in the rocks which are to be seen between Morthoe and Woolacombe. The same beds have doubtless been several times repeated, but in some of the broken folds it is probable that there are strata which belong to very different horizons. Moreover, there is a somewhat marked difference in some of the deposits. The flaggy beds which alone enable us to make out the folds are succeeded by fine-grained dark slates, and as these are found at a height of about 500 feet in the hill above Barricane, it is clear that they alone must attain to a thickness of several hundred feet.

### III. ROCKHAM BAY, BULL POINT, LEE BAY, LEE, AND SLADE.

Near the centre of Rockham Bay there is a well-marked fold in which are some hard, gritty bands, and on the northern side dark bluish-grey slates, which have yielded some small *Lingulæ*, but no other distinguishable fossils. Between here and Bull Point there are indications of another broken fold, and at Bull Point the dip is N.N.W. in striped grey flaggy beds, which exhibit extensive shiny cleaved surfaces. Similar rocks in well-marked folds are found extending along the coast towards Lee Bay. In flags obtained from a quarry on Flagstaff Hill, on the south-western side of Lee Bay, I obtained some very large *Lingulæ*. On the eastern side of the same bay are much crushed slates with fucoid-like markings on the surface, and in the cliffs towards Shag Point are greenish and yellowish flaggy beds, sometimes stained of a pinkish colour. Small *Lingulæ* were fairly abundant in some of these beds. Between Shag Point and Flat Point the beds are much broken, and there are clear indications of an important fault. Beyond the fault towards Ilfracombe the rocks are more massive in character, and as they also contain many sandstone-bands, and have not yielded any fossils, I have, for the present, thought it well not to include them with the Morte Series. They are also separated from the typical Ilfracombe Beds by a fault, which extends along the depression between Langley and the coast. These beds are well exposed in the Slade quarry, dipping S. at a high angle at its western end, and folding round to the N. at its eastern end, where there are beds of reddish and yellowish sandstones. These rocks call to mind some of the Pickwell Down sandstones and shale-beds; but it must be admitted that at present their age, owing to the absence of fossils, is indeterminable. In the Lee valley I found a few *Lingulæ* and fragments of encrinites at several points in the Morte Series, and in the quarry opposite the hotel small *Lingulæ* are as abundant as at Morte Point.

## IV. MULLACOTT, SHELFIN, AND ILFRACOMBE.

The discovery by me in 1891 of a fairly rich fauna in a quarry on Mullacott Farm, having a strong Silurian facies, led me to make a careful examination of the boundary-line between the Morte Series and the Ilfracombe Beds in this area, and to note any special changes visible in the beds near the junction. During this examination it soon became apparent that there was no gradual passage between the Ilfracombe Beds and the Morte Slates, as had previously been maintained to be the case, but that there was everywhere an important petrological difference to be noticed, which could only be the result of beds of very different age being brought into contact either by a fault or an unconformity. To enable me to make out what was really the cause of this abrupt change, I found it necessary to trace with care the Ilfracombe Beds to the north in coast-sections and in the valleys about Ilfracombe, and evidence was soon obtained to show that where beds had been indicated as dipping regularly to the south, and hence under the Morte Slates, they as often dipped in the opposite direction, that they were bent into a series of acute folds, and that the strong cleavage had often been mistaken for bedding-planes. After this it became possible to follow certain well-marked beds through the various folds, and to make out that these rose up higher and higher in the sections as we approached the Morte Slates, and indicated the southern edge of a well-marked trough, as shown in fig. 2. Further examination revealed the fact that there was marked evidence of much crushing where the Ilfracombe Beds were in contact with the Morte Slates, and therefore that the line of separation here, at least, was an important thrust-fault.

Much of the evidence, so far as it relates to the Ilfracombe Beds, has already been given by me in a paper in the *Geol. Mag.* for 1893, therefore it is only necessary now to refer to that portion of the evidence which more particularly explains the nature of the junction between the Ilfracombe and Morte Beds. The Ilfracombe Beds are often much broken by faults and frequently inverted, but there are well-marked petrological and palæontological horizons which enable the beds, even when most disturbed, to be identified; therefore, though beds at different horizons are occasionally brought into contact with the Morte Slates, the line of junction, when these facts are borne in mind, can be, as a rule, easily traced.

In Mullacott Hill there is very little superficially to mark the fault-line, but just above Score, in a quarry worked for road-metal, some massive sandstone-beds of the Ilfracombe Series, though in a greatly crushed condition, are seen dipping away from the Morte Beds. North of Great Shelfin the fault runs along a narrow valley, the hill on the northern side being formed by the basal sandstones of the Ilfracombe Series, and that on the southern side by the Morte Beds. In an easterly direction the fault crosses the Oakridge, and afterwards extends through the valley which runs nearly east and west, north of Bowden.

The sandstones of the Ilfracombe Beds remind one much more

strongly of the Pickwell Down Sandstones than of any found in the Morte Series, and, like the former, they contain an abundance of detrital mica. The slaty beds in the Ilfracombe Series also are often highly micaceous. It is necessary to bear these facts in mind, for though on the northern side of the Ilfracombe trough, as at Combe Martin and the Hangman Hills, the beds are as little changed as they are on Pickwell Down, yet on the southern side, near the great fault, they are often so much crushed and broken that the superficial likeness is not at once evident. Moreover, the lowest beds are nowhere seen in this area. On Mullacott Hill there are several quarries which have yielded fossils, but that which has yielded most specimens is on the right side of the road leading from Ilfracombe to Morthoe Station, and less than  $\frac{1}{4}$  mile south of the Ilfracombe Cemetery. The beds of purplish, greenish, and yellowish slates dip at an angle of about  $70^\circ$  to E.S.E. On the northern side of the quarry large *Lingulae* are fairly plentiful, but the majority of the other fossils were found in the beds on the southern side. They comprise *Stricklandinia lirata* (some specimens of very large size), *Orthis rustica*, *Rhynchonella Stricklandi*, a new *Pterinea*, *Cardiola interrupta* (?), encrinites, fragments of a crustacean, etc. The horizon indicated seems to be the base of the Wenlock. In the valley east of this quarry, which separates the Mullacott from the Shelfin ridge, there are several outcrops of the slates, and these have also yielded fossils, chiefly *Lingulae*. In some quarries in Shelfin Wood, on the northern side of the Shelfin ridge, the slates are covered with markings resembling graptolites in a bad state of preservation. The other fossils found along with these are a few *Lingulae*, one or two specimens of *Stricklandinia lirata*, and fragments of encrinites. In searching for fossils in the Morte Slates it must always be

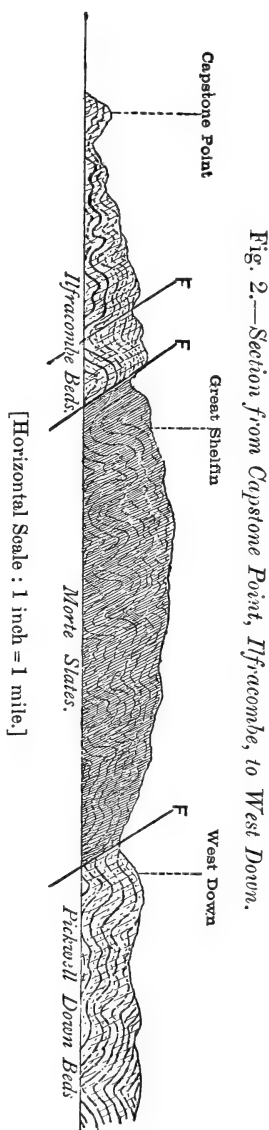


Fig. 2.—Section from Capstone Point, Ilfracombe, to West Down.

remembered that the beds are much folded, and that fossils can only be found in anything like a fairly well-preserved state in the limb of the fold where the cleavage-lines and bedding-planes are nearly parallel. In the arch of the fold the fossils are much crumpled, and where the cleavage crosses the beds fragments only are found, though a sharp blow directed in the line of the bedding, which is usually much less marked than the cleavage-line, will sometimes reveal a better specimen. Eastwards from this point the Morte Slates are frequently exposed in small quarries and roadside sections, but there are no quarries of any importance until we reach the neighbourhood of Francis and Woolscott Barton. In the Francis quarry are some thick beds of a yellowish shale, unlike the usual Morte Slates, and, as they have not yielded any fossil evidence other than worm-tracks and doubtful encrinurites, there is nothing to guide one as to their proper horizon.

#### V. WOOLSCOTT BARTON, SMITHSON, AND BERRY DOWN.

On Woolscott Barton Farm there are several old quarries in the Morte Slates, but in none of these could I find more than traces of fossils. In the slate-quarry in Smithson Wood, on the eastern side of the valley which separates the Woolscott and Smithson farms, many markings resembling graptolites were found on the surface of the slates, also a few small *Lingula*, a small *Orthis*, and fragments of encrinurites. The slates are of a dark-bluish colour and well cleaved. Similar slates are found in the road-cutting leading to Smithson Farm. In the valley a short distance south of the adjoining farm of Hempster I noticed some light-coloured felstone-dykes cutting through the slates. At Berry Down the Morte Slates rise to a height of over 850 feet, but there are no quarries here of any importance. On the road from Berry Down to Combe Martin the line of separation between the Morte Slates and the Ilfracombe Beds occurs near Henstridge, and the fault runs up the valley which extends for some distance in a nearly east-and-west direction. Sandstones are found in the southern side of Stoneditch Hill underlying the slaty and calcareous beds of the Ilfracombe Series, which are much folded here, as at Ilfracombe. Evidence that the Ilfracombe Beds lie in a wide trough becomes perfectly clear in tracing the sections towards Combe Martin, and identifiable fossils are to be found at several points. The fossils here are, on the whole, in a better state of preservation than near Ilfracombe, and the facts seem to point to a diminishing intensity in the folding and shearing in an eastward direction.

#### VI. SUMMARY OF THE STRATIGRAPHICAL EVIDENCE IN NORTH DEVON.

It may be well briefly to summarize the results given in this paper, though any conclusions arrived at in regard to the general

succession of the rocks in North Devon will come in more appropriately after the second part of the paper, which will contain the evidence obtained from other areas, has been read before the Society.

The changed position now given to the Morte Slates removes one of the greatest difficulties experienced by previous writers in their attempts at correlating the strata in North Devon with those in other areas, for nowhere else had such a thick series of well-cleaved slates been met with at the horizons assigned to them here. The horizons necessarily varied in accordance with the views in regard to the succession held by the authors. Those who held with Prof. Jukes that there was but one group in North Devon of sandstones, slates or shales, and calcareous beds, repeated by faults, found it necessary to place the Morte Slates at the top of the whole series; while those who claimed that there were two or more series of somewhat similar sediments conformable to one another placed them not far from the centre in the succession. There is good evidence at many points to show that Prof. Jukes was correct in claiming a faulted junction between the Morte Slates and the Pickwell Down Beds, but the results produced by the faults are different from those which he suggested; for, instead of one great broken trough with the Pickwell Down Beds coming up from under the Morte Slates, we find the former resting upon the latter, the faults between being due to crushing during the movements which brought the Morte Slates and the Pickwell Down Beds to the surface.

Until the thrust-fault between the Morte Slates and the Ilfracombe Beds on the northern side had been made out, the only way by which a repetition of the beds could have taken place would be by a great fault on the southern side; but this would necessitate a much greater displacement of the beds than by that which is now known to occur on the northern side of the Morte Slates.

The discovery of fossils in the Morte Slates belonging to several horizons in the succession, and some probably as low in position as the base of the Silurian (Upper Silurian of the Geological Survey), added to the stratigraphical evidence, enables us now to speak with confidence as to their place in the succession in North Devon. They are the oldest rocks in the area, and they do not appear to contain amongst them any beds newer than Lower Devonian. In some places newer rocks may occur amongst them as the results of faults or unconformities, but not in order of succession.

In the second part of the paper evidence will be given to show that in at least one of the areas examined there appears to be a passage from some of the Morte Slates to Lower Devonian rocks containing so characteristic a fossil as *Phacops* (*Cryphæus*) *laciniatus*. These passage-beds lie on the southern side between fairly typical Morte Slates and Pickwell Down Sandstones, and in the latter, quite near one of the junctions, we discovered a band rich in fossil wood, and other evidences indicating that they had been deposited near land. When an interpretation of the succession in North Devon and West Somerset, in accordance with the evidence

recently obtained, is submitted, I think it will be seen that it agrees far more closely with that which has been made out in other areas in the British Isles than has hitherto been suspected.

## VII. DESCRIPTION OF THE FOSSILS FOUND IN NORTH DEVON.

### LINGULA MORTENSIS, sp. nov. (Pl. X. figs. 1-5.)

This is probably the largest *Lingula* yet found in the British Silurian rocks, and it occurs very plentifully in the Morte Slates, though usually in a distorted condition. Elongated oval, the sides nearly parallel. Rather acutely rounded in front, and tapering gradually backwards towards the beak. Valves compressed, and surface marked with numerous fine lines of growth, which here and there are sculptured with cross markings.

Length 24, width 9 lines.

In size and shape it more closely resembles *L. Brodiei*, Davidson, from the Woolhope Limestone, than any other species described from the British Palæozoic rocks; but it is larger than that species, and longer in proportion to the width. As one specimen only of *L. Brodiei* has been figured and described, it is possible, when others have been discovered, that they may be found to agree more closely with our shell, especially as they occur on the same geological horizon. In association with the large forms there are others of various sizes, and some of the surfaces are thickly covered with minute specimens as in Pl. X. fig. 5.

Found at Woolacombe, Morte Point, Lee, Mullacott, and Shelfin.

### STRICKLANDINIA LIRATA, Sowerby. (Pl. X. figs. 6-8.)

This is the most characteristic fossil in the Mullacott quarry, but though it occurs there in fair abundance it is most difficult, owing to the crushing and cleavage, to obtain any good specimens. Those, however, which have been found show that it attained a large size, equalling nearly the largest forms found in the Wenlock Beds of the Island of Gothland.

According to Davidson, *Stricklandinia lirata* 'varies greatly in its external shape... The size and regularity of the ribs are especially variable in different specimens, as well as the length of the hinge-line.' (Monogr. Pal. Soc. 'Brit. Sil. Brachiop.' vol. iii. pt. vii. p. 161.)

The suggestion first made to me by Mr. Sharman, of the Museum of Practical Geology, that our fossil seemed more closely allied to *S. lirata* than to any other brachiopod with which he was acquainted, tempted me to make an examination of many of the specimens in our museums; and the fact, stated by Davidson, of its tendency to vary greatly in shape and ornamentation I found very true. I cannot say that, so far, I have been able to exactly match our fossil with any other specimen, but undoubtedly it approaches most closely in its size and ornamentation the specimens in the Society's Museum and in the Jermyn Street Museum, from the lowest beds of Wenlock age at Marloes Bay, Pembrokeshire, and those from Gothland in the Natural History Museum. The following characters, abstracted from those



given by Davidson in the full description in his memoir, published by the Palæontographical Society, vol. iii. pt. vii. p. 159, can be made out in our specimens :—‘ Transversely oval ; hinge-line nearly straight and shorter

than the width of the shell . . . sides and front rounded.

Valves moderately convex. Dorsal valve

more or less semi-circular and trilobed,

from the presence of a rather wide mesial

fold of small elevation which, commencing

at the extremity of the umbonal beak,

gradually widens as it approaches the front.

Surface of valves ornamented

with numerous angular, irregular, often

bifurcating ribs, and concentric lines of

growth. Near the umbo of the dorsal

valve are two elongated pear-shaped

impressions, due to the adductor or

occluser muscles, divided in the middle

by a central ridge. Numerous pits (rough

tubercles on the cast), probably ovarian

markings, surround these scars.’

The specimens are so much compressed,

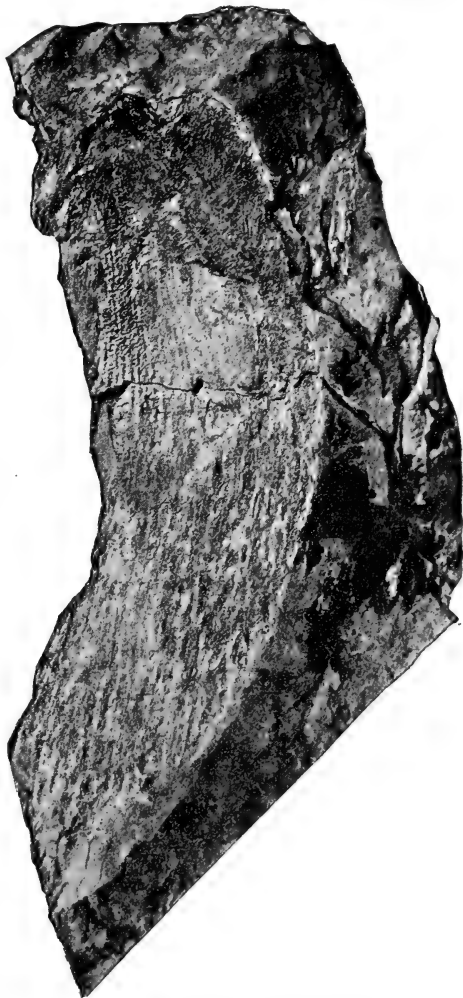
and also drawn out of shape by the cleavage,

that it was only by the examination

of a large number that all these points

could be clearly made out. There can, however, be no doubt that the fossil is either *S. lirata* or a very closely-allied species. It is an important fossil in defining the horizon, and the other fossils

Fig. 3.—*Impression of Stricklandinia lirata from Mullacott Quarry. (Natural size.)*



[Reproduced from a photograph.]

found in the same quarry are such as would be expected to occur with it in beds of Lower Wenlock age.

Found in the Mullacott and Shelfin quarries, near Ilfracombe.

*RHYNCHONELLA LEWISII* (?), Davidson. (Pl. XI. figs. 1-4.)

Many specimens of this species have been found in the rocks on the side of the path leading down to Barricane Beach, but, like most of the fossils found in the Morte Slates, usually in a greatly distorted condition. The specimens have also for the most part lost the ornamentation characteristic of this species, but traces of it are sometimes left in some of them. The pinched appearance of the mesial fold is still retained, and the number of ribs in the mesial fold and sides agrees exactly with those in the Shropshire specimens from beds of Wenlock age. On p. 180, *op. cit.*, Davidson says that 'the range of this species is said to be in the Llandovery and Wenlock rocks; I am, however, acquainted with the shell only from the last-named formation, in which at some localities it is exceedingly abundant.' Hitherto the only locality in the Morte Slates in which it has been found by us is at Barricane in Morte Bay, in association with *Spirifera Hamlingii*, *Lingula mortensis*, etc. Mr. Bather was kind enough to compare our specimens with those in the Natural History Museum, and said that they agreed more closely with the typical specimens of *Rh. Lewisii* in the National Collections than with any other species.

*RHYNCHONELLA STRICKLANDI* (?), Sowerby. (Pl. XI. fig. 11.)

A few imperfect specimens of this species have been found in the Mullacott quarry. In size and shape the shell agrees with those which occur in the Wenlock Limestone and Shale in other areas. It has a very convex form, is from 12 to 15 lines in length, and the surface is ornamented with from 25 to 30 narrow, simple, angular ribs.

*SPIRIFERA HAMLINGII*, sp. nov. (Pl. XI. figs. 5 & 6.)

The specimens are compressed and distorted, but they show that the shell was wider than long and moderately convex. The hinge-line is nearly straight, rather longer than the width of the shell, and somewhat pointed at the cardinal angles. Dorsal valve convex, with a well-raised, wide, mesial fold. Surface of valves ornamented with about 36 moderately strong rounded ribs, of which nearly a third occur on the mesial fold. They are frequently crossed by fine concentric lines, and here and there the larger ribs appear to be ornamented with fine lines more or less parallel with them. Area narrow.

Found at Barricane, in Morte Bay.

*ORTHYS RUSTICA*, Sowerby. (Pl. XI. figs. 7-10.)

This species occurs in fair abundance in the Mullacott quarry, and a few specimens have also been obtained from the rocks on the northern side of Barricane Beach. In each place they are much distorted, but they show the characteristic ornamentation mentioned by Davidson. He says at p. 239 (Monogr. Pal. Soc. 'Brit. Sil. Brach.')

that 'I must now again remind the student that one of the chief characteristics of *Orthis rustica* consists in its generally having a small interpolated rib between each two of the longer ones, or between those which extend directly from the extremity of the beaks to the margin, the number of ribs varying according to the age of the individual.' Among the specimens collected at Mullacott there are examples of all sizes, and some quite as large as the largest found in the Wenlock rocks of Shropshire. Its association here with *Stricklandinia lirata* is highly interesting, and important in defining the horizon of the beds; with the exception of *S. lirata* and *Lingula mortensis*, it is about the most plentiful fossil in these beds.

Found at Mullacott and Barricane.

**MODIOLOPSIS BARRICANENSIS**, sp. nov. (Pl. XI. figs. 14 & 15.)

This species approaches more nearly in shape *Modiolopsis subalatus*, Hall, of the Niagara Group, than any British species. It is, however, a much larger form than the American species, and the umbo is situated nearer the anterior extremity.

Length about 14 lines, greatest width about 7 lines. Sub-rhomboidal in shape, posterior side greatly expanded. Anterior extremity short and rounded. Umbo prominent. Surface marked with moderately strong concentric lines, and near the anterior end the concentric lines are crossed by numerous fine lines which extend to the margin.

The shell is still convex near the umbo, but it has evidently been much flattened by pressure.

Found in the cliffs on the northern side of Barricane, and Mullacott quarry.

**PTERINÆA MORTENSIS**, sp. nov. (Pl. XI. figs. 16, 17.)

Several specimens have been found in the Mullacott quarry, which exhibit characters sufficiently marked to indicate a new species differing in several particulars from any other known British form. The specimens are crushed and evidently somewhat distorted, but show that the shell must have been broader than long, with a nearly straight hinge-line. Anterior wing short and pointed, and separated from the central part of the shell by a sulcus. Posterior wing long and obtusely pointed. The surface of the shell is marked by numerous radiating striæ, which bifurcate as they approach the margin. Some specimens show traces of concentric lines of growth. The umbo is prominent, and situated about a third of the distance from the anterior extremity.

Width 16, length 10 lines.

Found, up to the present, only in the Mullacott quarry.

**AVICULA**, sp. (Pl. XI. fig. 18.)

No perfect specimens have been found, but the fragment figured shows that it is distinct from any British species. It, however, somewhat closely resembles one of the species (*Avicula undata*) from the Niagara rocks of America.

Found in the cliffs, northern side of Barricane.

## EXPLANATION OF PLATES X. &amp; XI.

## PLATE X.

- Figs. 1-4. *Lingula mortensis*, sp. nov. 3<sup>a</sup>. Enlarged portion of shell, showing ornamentation. Fig. 5. Probably young specimens of the same species. Mullacott, Shelfin, and Morte Point. Author's Collection.  
 Figs. 6-8. *Stricklandinia lirata*, Sowerby. Mullacott Quarry. 6, Collection of the Rev. G. F. Whidborne; 7 and 8, Author's Collection.  
 Figs. 9, 10. *Crania*, sp. Mullacott Quarry. Author's Collection.

## PLATE XI.

- Figs. 1-4. *Rhynchonella Lewisii* (?), Davidson. Barricane, in Morte Bay. Author's Collection.  
 Fig. 11. *Rhynchonella Stricklandi* (?), Sowerby. Mullacott Quarry. Author's Collection.  
 Figs. 5 & 6. *Spirifera Hamlingii*, sp. nov. Barricane, in Morte Bay. Author's Collection.  
 Figs. 7-10. *Orthis rustica*, Sowerby. Mullacott Quarry. Author's Collection.  
 Figs. 12 & 13. *Stricklandinia*, sp. Mullacott Quarry. Author's Collection.  
 Figs. 14 & 15. *Modiolopsis barricanensis*, sp. nov. Barricane, in Morte Bay, and Mullacott Quarry. Author's Collection.  
 Figs. 16 & 17. *Pterinea mortensis*, sp. nov. Mullacott Quarry. Author's Collection.  
 Fig. 18. *Avicula*, sp. Barricane. Author's Collection.  
 Fig. 19. *Cardiola interrupta* (?), Sowerby. A fragment, much enlarged. Mullacott Quarry. Author's Collection.  
 Fig. 20. A fragment of a Crustacean (carapace ?). Author's Collection.

## DISCUSSION.

The PRESIDENT said that six years had elapsed since the Author attacked the problem of the rocks of North Devon and their succession. On the former occasion he obtained a verdict of 'not proven.' After further careful work on these beds, the Author now came forward with additional evidence from the field and from the fossils derived from the rocks to prove that his reading of the succession of the Devonian rocks is the true one. He (the President) invited discussion (1) on the stratigraphical, and (2) on the palæontological evidence.

Prof. HUGHES believed that the thickness of the several divisions of the Devonian had been greatly exaggerated, and that the vertical distance of the beds, now proved by Dr. Hicks to be fossiliferous, from the known fossil-bearing beds of Hele, for instance, was not really great. He thought that, although the lithological difference between the main mass of the Morte Beds and of those which occurred on either side of it was very great, there were alternations of the sandy and slaty type in the contiguous strata. In so disturbed an area faults would be apt to occur where rocks of unequal resisting-power were crushed together, and this, with the overfold of the anticlinal arches, might give a deceptive appearance of an unconformable junction. The proof of the theory proposed by the Author depended chiefly upon the palæontological evidence. Taking the more important test-fossils laid upon the table, namely, *Cardiola interrupta*, *Stricklandinia lirata*, and the

graptolites, he thought that the first was an imbricated shell, like an *Atrypa*, perhaps *A. aspera*, but that it certainly did not show the cross-ribbed surface from which *C. interrupta* took its name. The second was founded on distorted specimens of *Spirifera disjuncta*; and the so-called graptolites were lines of an asbestiform mineral following broken vein-like cavities, which had perhaps in some cases been occupied by encrinite-arms and stems, the joints of which, together with regular step-like displacements during the movements that modified the structure of the rock, produced the scalariform appearance of graptolites.

The Author had added greatly to our knowledge of the Devonian rocks by his discovery of fossils in the Morte Series, but the speaker thought that the rocks and fossils suggested a comparison with the Tintagel Beds rather than with the Silurian.

The Rev. G. F. WHIDBORNE had had the privilege of following the Author's work in the field and collecting fossils with him, and he was convinced that the Author had not only found an abundant fauna in the 'unfossiliferous' Morte Slates, but had discovered the true bedding-planes, and thereby proved the thickness of the deposits in North Devon to be much less than had been supposed. He had very carefully examined the fossils on the table, and was convinced that they did not present a Devonian facies. He had been unable to reconcile them with any Devonian fauna that he knew. Nor could he agree with Prof. Hughes that the large specimen of *Stricklandinia lirata* could by any possibility be a distorted *Spirifer Verneuvili*. It differs from that form both in shape and minute ornament. The fragment of '*Cardiola interrupta*?' also seemed to be more like that fossil than anything else, though it was difficult to determine in its fragmentary condition. It certainly was not *Atrypa aspera*.

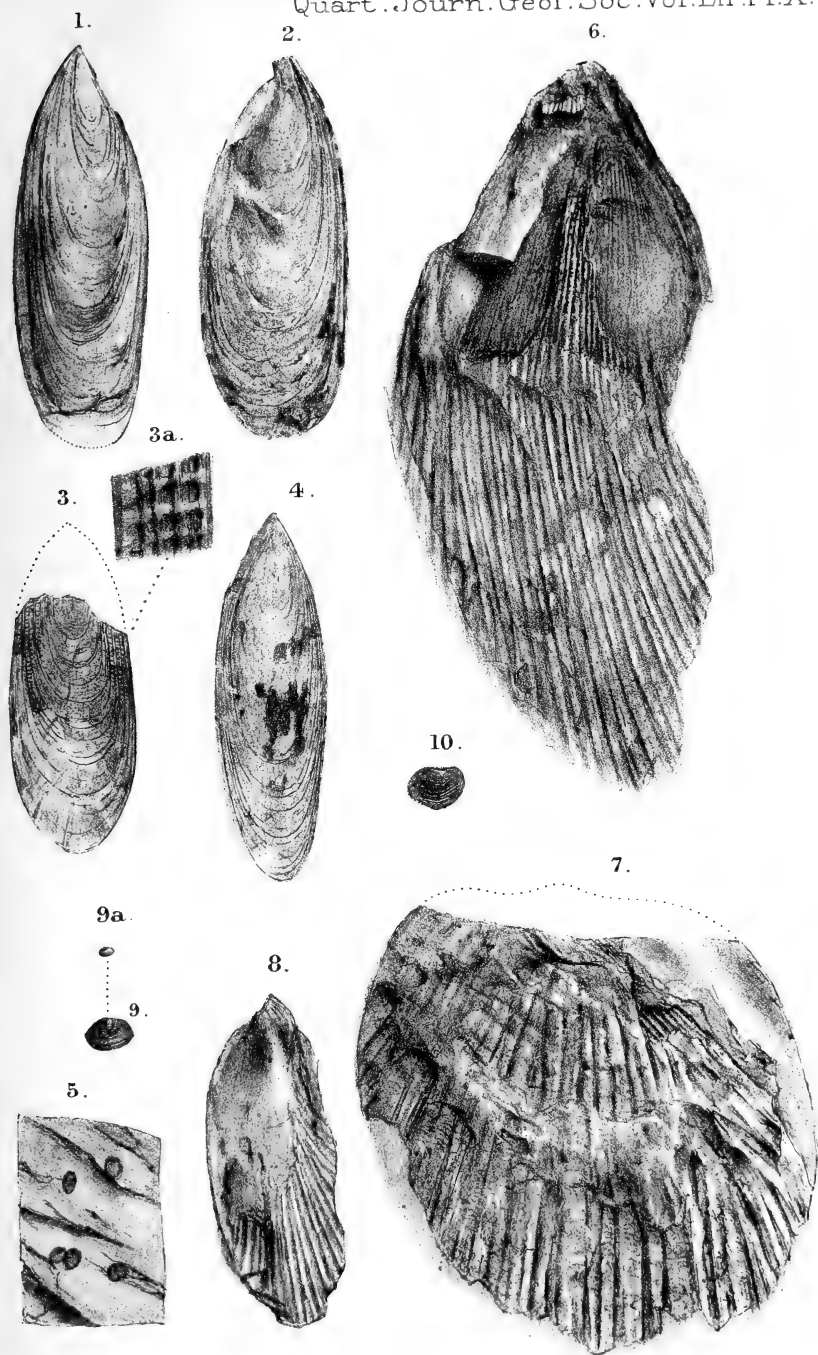
Mr. MARR said that the dip of the Ilfracombe Beds from the Morte Slates below the supposed thrust-plane was not evidence of the existence of a thrust-plane. But the serious evidence was that of the fossils. He maintained that none of the fossils exhibited were definitely proved to be Silurian. He could not see any indications of graptolitic structure in the specimens on the table. The greatest stress had been laid on the supposed *Stricklandinia lirata*. He wished that the gentleman who had identified that specimen had been present to say definitely that it was *Stricklandinia*. Considering the number of forms closely related to Silurian forms which had been found in American Devonian rocks (for example, *Pentamerus pseudogaleatus*), and the fact that in the richly fossiliferous deposits of Bohemia, Barrande's stages F, G, H, now shown by Kayser to be Devonian, were originally described as Silurian, he did not think that the distorted fossils displayed on the table could be taken as evidence for upsetting the received classification of the North Devon rocks. The Author was to be congratulated on the discovery of fossils in these supposed barren rocks, but the speaker, though having no objection to the reference of the Morte Slates to the Silurian, hoped that more evidence would be forthcoming in the

second part of the paper before they were definitely accepted as such.

Mr. H. B. WOODWARD remarked that the Devonian system had always suffered from being founded on zoological characters without clearly defined stratigraphical evidence. The Author's paper should be studied in conjunction with the excellent work of Dr. Hinde and Mr. Howard Fox on the radiolarian rocks, which were probably of the age of our Yoredale Beds. The precise equivalents of the lowermost Carboniferous in Devon were not established, and there had been no base to the Devonian system. For the sequence of Devonian faunas we had to take the divisions made in Germany; and as it was not clear that the base of the Carboniferous there was the same as that in this country, it might be questioned whether the continued use of the term 'Devonian' was justified. Agreeing that the subdivisions in Devon must be worked out by their fossils, he hoped that in so complicated a region the species would be identified solely from their zoological characters, while the best basis for such detailed work was an independent 6-inch survey of the area.

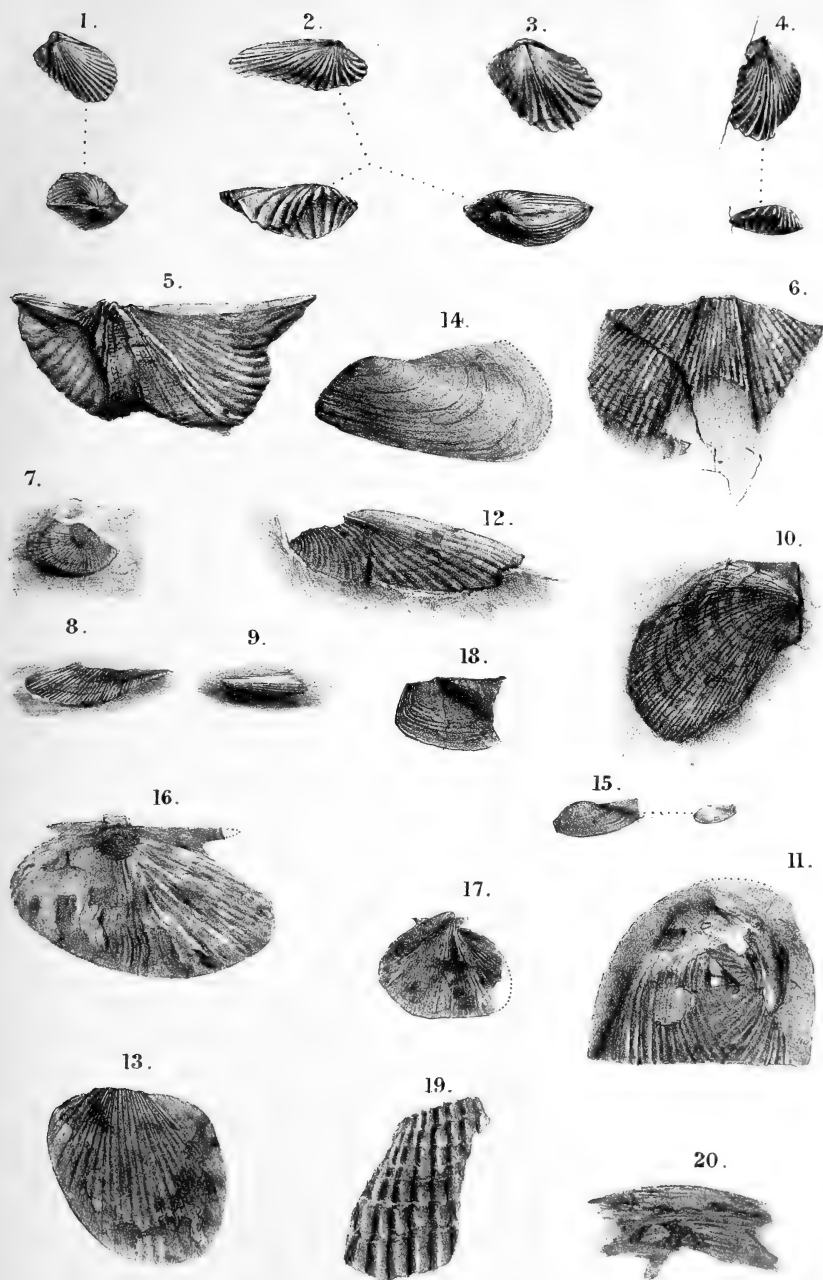
Mr. HOPKINSON said that he had examined numerous specimens collected by the Author which bear a general resemblance to graptolites, and of which he exhibited drawings made under the microscope. Some of these might not be organic, others might be worm-tracks or encrinite-stems, or impressions of other organisms, but he felt certain that there were graptolites among them; they were, however, in so bad a state of preservation that it was impossible to identify them. He believed that most of the graptolites belonged to the genus *Monograptus*, and therefore were of Silurian age, but that Ordovician genera also occurred, showing that the rocks from which they had been obtained were of different horizons. Some of the branching forms were probably *Cladophora*, belonging to the genus *Dendrograptus*. He could not believe it possible that mineral matter could simulate, as suggested by Prof. Hughes, such forms as he then drew on the blackboard, one being typical of the *Monograptus Sedgwickii* group (having long curved denticles), and another resembling a scalariform impression of a *Climacograptus* (with transverse oval cell-apertures). He hoped that specimens would be obtained in a sufficiently perfect state of preservation to enable them to be specifically identified, dispelling all doubt as to their nature.

The AUTHOR said that he would reserve his reply until the second part of the paper is read, when evidence will be presented which will clear up many points referred to in the discussion. There can be no doubt that the Morte Slates, in their lithological characters and in their fossil contents, are entirely unlike the surrounding Devonian rocks.











14. *On the Llandovery and Associated Rocks of Conway (North Wales).* By Miss G. L. ELLES and Miss E. M. R. WOOD, Bathurst Students, Newnham College, Cambridge. (Communicated by J. E. MARR, Esq., M.A., F.R.S., Sec. G.S. Read January 8th, 1896.)

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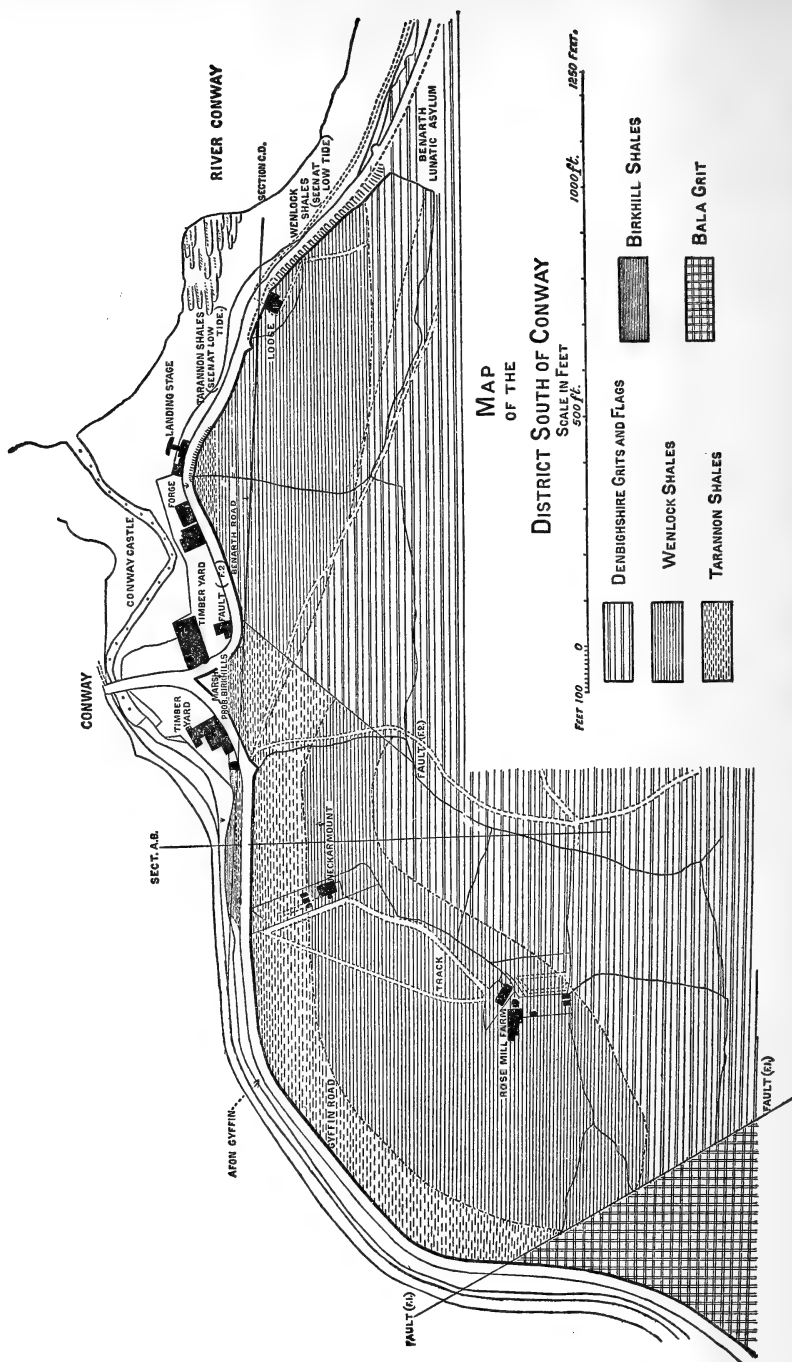
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## I. INTRODUCTION, AND DESCRIPTION OF AREA.

THE Geological Survey Map (Sheet 78 N.E.) of the district lying immediately south of the town of Conway reveals an outcrop of Tarannon Shales, which is curious as regards its relation to the associated formations, since the Tarannon Shales are represented as being both underlain and overlain by rocks of Wenlock age. This circumstance led us to examine this special area; and our attention having already been directed to the occurrence of graptolitic shales below the Tarannons in other parts of Wales, we thought it possible that they might also be present in the Conway district.

Our observations in that district have extended over a fairly wide region, including the greater part of the valley of the Afon Gyffin between Conway and Y-Ro; but the only area which we have mapped in anything like detail lies immediately south of the town of Conway itself, and occupies the hill opposite Conway Castle and the railway. This area is bounded on the east by the River Conway, and on the west by a fault ('boundary-fault,' as we term it in the following pages) which brings a calcareous grit of Bala age against Silurian beds.

The northern limit of the area is formed by the Afon Gyffin, a tributary stream of the River Conway, which it joins just below the Castle. The southern limit has been taken, for convenience, at the beginning of the dense woods belonging to Benarth Asylum. In other places higher up the valley, where we hoped to find a similar succession, the ground was low-lying and all rock-exposures were concealed beneath a tract of alluvium.



# MAP OF THE DISTRICT SOUTH OF CONWAY SCALE IN FEET 500 ft.

The geological structure of the area is fairly simple, though the beds are faulted and give indications of having been disturbed, the cleavage in many cases being in a direction at right angles to that of the plane of bedding. There is no great variation in the lithological characters of the beds; they are all of the general type known as 'greywacke,' and graduate locally from thick-bedded gritstones, through smooth flagstones, and thin-bedded hard grey shales down to fine-grained graptolitic mudstones. The only fossils with which we have to deal are graptolites, and their value for purposes of stratigraphical correlation is now too well known to need comment.

## II. LITERATURE.

The succession of rocks at Conway has received but little attention at the hands of geologists, and the literature is in consequence somewhat scanty. In the second edition of the Geological Survey Memoir on North Wales (1881) the succession at Conway is given as follows:—

Wenlock Shale.	} Wenlock Beds.
Denbighshire Grit.	
Tarannon Shale.	
(Upper and Lower Llandovery Beds absent.)	
Caradoc or Bala Beds.	

It is also suggested that the absence of Llandovery rocks between Conway and the country east of Bala Lake may possibly be due to the overlap of the Tarannon Shales, which are said to rest on Lower Silurian rocks at about the horizon of the Bala Limestone.

The Tarannon Shales form a narrow band at the base of the Denbighshire Grits extending from Conway to Llanbedr, about 5 miles to the south, being interrupted only by three small faults with a downthrow to the east.

On the hill immediately south of Conway the base of the grits, resting on a narrow band of Tarannon Shales, strikes towards Gyffin and, dipping east at an angle between 10° and 30°, passes south by Y-Ro to Caerhun, where the western boundary is lost in the alluvium of the River Conway. It is also stated that the grits pass up into the Wenlock Shale, but no mention is made of the considerable thickness of Wenlock Shale which we have found below the lowest grit-band in this district.

Prof. Lapworth, in his classical work on the 'Distribution of the Rhabdophora' (Ann. & Mag. Nat. Hist. ser. 5, vols. v. & vi. 1880, pp. 45, etc.), records the occurrence of many graptolites in the Tarannon Shales of Conway. On palæontological grounds he concludes that the Tarannon Shales of Conway correspond to the lowest portion of the Gala Group of Southern Scotland, that is, with the zone of *Monograptus exiguus*.

Our work necessitates a modification of the views of the earlier Surveyors, though we are in complete agreement with Prof. Lapworth's suggestion as to the horizon of the Tarannon Shales of this district.

## III. GENERAL SEQUENCE.

In this area we believe that we have a succession of graptolitic mudstones representing beds of Llandovery, Tarannon, and Wenlock ages, and we hope to show that the omission of Llandovery Beds in the Conway succession of the earlier surveyors was erroneous. We consider that the general sequence in descending order is as follows:—

5. Denbighshire Grits and Flags.
4. Wenlock Shales.
3. Tarannon Shales.
2. Upper Llandovery Beds.
1. Bala Beds.

The junction between the Bala and Llandovery rocks is nowhere visible. The former do not come to the surface south of the Afon Gyffin, but at the time of our first visit drainage-operations were in progress along the road passing the timber-yard on the way to Benarth, and at a few feet below the level of the road black graptolitic shales containing *Diplograptus foliaceus* (Murch.) and *Climacograptus bicornis* (Hall) were seen, apparently *in situ*, underlying the Tarannon Shales. If this be really the case, the Lower Tarannon rests unconformably on rocks of Bala Limestone age, and the succession is here different from that seen on the other side of the fault (F. 2 in map, p. 274), where Llandovery rocks occur, but it is unlikely that the Birkhill Shales have been overlapped in this short distance.

Since there is no junction visible between the Bala and Llandovery rocks, we are unable to determine definitely whether the Lower Llandovery rocks are absent or not in the district.

*Note on the Bala Rocks of the Conway District.*—On the other side of the River Conway, in a quarry of Bala rocks on the hill above Deganway, we have found remains of several large trilobites. Many seem referable to the species *Phacops appendiculatus* (Salt.) (= *P. eucentra*, Ang.?). This would tend to show that we have here representatives of the Ashgill Shale fauna of the Lake District. If this be the case, there exists in this part of North Wales a higher series of Ordovician rocks than has hitherto been supposed, and hence the break between Ordovician and Silurian rocks is less than was formerly believed to be the case.

The Upper Llandovery rocks pass up conformably into the Tarannons; but on palæontological grounds we believe that the latter are overlapped by the Wenlock Shales, and that the highest beds—that is, the zone of *Cyrtograptus Grayæ* (Lapw.)—are not present here.

The best section of the Wenlock Shales is to be seen on the shore below Benarth, and here we approximately determined the upper limit of these beds, on lithological grounds, at a point where the beds become more flaggy in character and contain bands of grit.

The exposures on the side of the hill were not sufficiently good to enable us to determine the upward limit with certainty.

There are two main faults in this district: one (F. 1), as has been mentioned above, forms our boundary-line to the W. and strikes  $10^{\circ}$  W. of N.; while a second one (F. 2), striking  $30^{\circ}$  S. of W. and

Fig. 1.

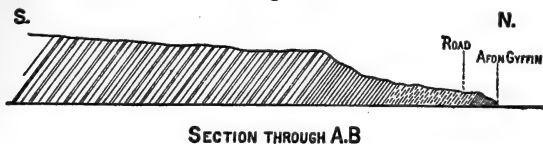
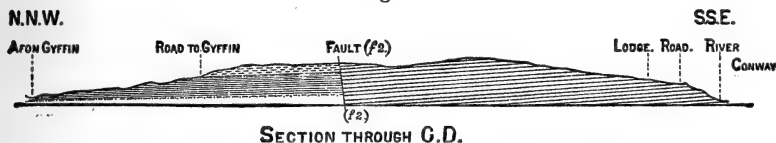


Fig. 2.



with a downthrow to the E., brings the Upper Llandovery and Tarannon beds against the Wenlock Shales. We believe that the occurrence of Upper Llandovery Beds is dependent in a great measure on this second fault.

#### IV. DETAILED DESCRIPTION OF THE BEDS.

##### 1. The Llandovery Rocks.

Rocks which are undoubtedly of Llandovery age occur on the right bank of the Afon Gyffin, from opposite Neckarmount House to the timber-yard buildings. Farther W. they are concealed beneath the alluvium of the river. They strike  $10^{\circ}$  N. of W., and dip  $10^{\circ}$  W. of S. at an angle of about  $55^{\circ}$ . Continuing on this strike, they are again seen in vertical section in the high bank opposite the fork formed by the junction of the Benarth and Gyffin roads; here they occur slightly below the level of the road, and probably occupy the whole of the marshy ground lying between the road and the bank.

(a) *Stream-section*.—The beds seen in section near the stream are capable of the following subdivisions, in descending order:—

7. Hard grey bed.
6. Black shale-band, with *Rastrites maximus*.
5. Grey flagstones.
4. Black shale-band, with graptolites.
3. Grey flagstones.
2. Black shale-band, with graptolites.
1. Very tough flagstones.

1. *Tough Grey Flagstones*.—Little need be said of the unfossiliferous beds forming the base of the section. They consist of tough grey flagstones, and are well exhibited in the bed of the

stream. They call to mind strongly the so-called Barren Mudstones of Moffat (Lapworth, Quart. Journ. Geol. Soc. vol. xxxiv. 1878, p. 240) and other areas. They are about 4 feet thick, but their base is not visible.

2. *Black Shale-band*.—This band is composed of typical black mudstones; it is only a few inches thick, and is much weathered, so that large blocks are not obtainable. We identified the following graptolites:—

<i>Rastrites peregrinus</i> (Barr.).	<i>Monograptus gregarius</i> , Lapw. C.
<i>Monograptus Hisingeri</i> , var. <i>nudus</i> (Lapw.).	<i>Diplograptus tamariscus</i> (Nich.). C.
— <i>Hisingeri</i> , var. <i>jaculum</i> (Lapw.).	<i>Climacograptus normalis</i> (Lapw.).

(C=very common. c=common. R=rare.)

3. *Grey Flags*.—The black fossiliferous band No. 2 is separated from the band No. 4 by a foot of grey flagstones, very similar in character to those found at the base of the section.

4. *Black Shale-band*.—Very similar to band No. 2, but fossils are rather more abundant. This band is also of inconsiderable thickness. We have found in it the following fossils:—

<i>Monograptus concinnus</i> (Lapw.).	<i>Diplograptus sinuatus</i> (Nich.). C.
— <i>Hisingeri</i> , var. <i>nudus</i> , Lapw.	— <i>Hughesii</i> (Nich.).
— —, var. <i>jaculum</i> (Lapw.).	— <i>tamariscus</i> (Nich.). C.
— <i>gregarius</i> ? (Lapw.).	<i>Climacograptus normalis</i> (Lapw.).
— <i>lobiferus</i> (M'Coy).	C.

5. *Grey Flagstones*.—These differ in no particular from those already described.

6. *Black Shale-band*.—This, the uppermost black shale-band that occurs in the section, is by far the most important. It is exposed about 3 yards from the top of the bank, below the uppermost bed of grey flagstones. The bed weathers very deeply, and has a curious rough fracture which renders it easily recognizable. The band is richly fossiliferous, and has yielded the following graptolites:—

<i>Rastrites maximus</i> (Carr.). C.	<i>Monograptus lobiferus</i> (M'Coy).
— <i>gemmatus</i> (Barr.).	— <i>spinigerus</i> (Nich.).
— <i>distans</i> (Lapw.).	— <i>turriculatus</i> (Barr.). R.
<i>Monograptus argutus</i> (Lapw.).	<i>Petalograptus ovatus</i> (Barr.).
— <i>Barrandii</i> (?) (Suess).	— <i>palmeus</i> (Barr.).
— <i>concinnus</i> (Lapw.).	<i>Diplograptus sinuatus</i> (Nich.). C.
— <i>gregarius</i> (Lapw.). R.	— <i>tamariscus</i> (Nich.). C.
— <i>galaensis</i> (Lapw.). R.	— <i>Hughesii</i> (Nich.). C.
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.).	<i>Climacograptus normalis</i> (Lapw.).
— —, var. <i>jaculum</i> (Lapw.). c.	c.

(b) *Marsh-section*.—The beds seen in section in the bank of the marsh are, as before mentioned, a continuation of those seen by the stream, and here, as before, they dip steadily in towards the hill. The marsh, which occupies the space between the road and the bank, lies about 3 feet below the level of the road, but the ground rises somewhat towards the bank. Were it not for this depression, no Llandovery Beds would be seen here, as the band with *Rastrites*



*maximus* is found almost at the level of the road, and the black band No. 4 is only just visible at the foot of the bank. This band disappears almost at once when traced east or west, and the zone of *Rastrites maximus* is also lost at the level of the road on either side of the depression.

The section is, however, very interesting as affording an opportunity of studying the passage from the Llandovery rocks into the Tarannon Shales. There occurs in this place a graptolitic band above the zone of *Rastrites maximus*. This must be, from its position, either a passage-zone or the lowest bed of the Tarannon Shales. From the character of the fauna presently to be described, we prefer to regard it as a true passage-bed.

The following is the section seen at this locality, the strata being enumerated in descending order:—

	Ft.	In.
9. Spotted grey flagstones to summit.		
8. Black graptolitic band (probably passage-zone) .....	0	6
7. Grey flagstones, with hard gritty band about 1 inch wide at base .....	1	8
6. Shale band; zone of <i>Rastrites maximus</i> .....	1	0
5. Grey flagstones, unfossiliferous.....	1	0
4. Black shale-band, just visible.		

(The beds are numbered to correspond with those of the stream-section.)

From the nature of the exposure of No. 4, we scarcely expected to find any fossils. We succeeded, however, in obtaining a few graptolites, but these were too fragmentary for specific determination.

*Zone of R. maximus, Band No. 6.*—This band is easily recognizable by its characteristic fracture and mode of weathering. It has yielded the following graptolites:—

<i>Rastrites maximus</i> (Carr.). C.	<i>Monograptus gregarius</i> (Lapw.).
<i>Monograptus concinnus</i> (Lapw.).	R.
— <i>spinigerus</i> (Nich.)?	— <i>crassus</i> (Lapw.).
— <i>Hisingeri</i> , var. <i>nudus</i> , Lapw.	— <i>involutus</i> (Lapw.)?
C.	— <i>turriculatus</i> (Barr.). R.
— —, var. <i>jaculum</i> (Lapw.).	<i>Petalograptus ovatus</i> (Barr.).
C.	— <i>palmeus</i> (Barr.).
— <i>cyphus</i> (Lapw.).	<i>Diplograptus tamariscus</i> (Nich.). C.
— <i>galaensis</i> (Lapw.). R.	— <i>Hughesii</i> (Nich.). C.

It will be observed that in this locality and in the stream-section the zone of *Rastrites maximus* is characterized by the abundance of *Diplograptus* belonging to the species *Hughesii* (Nich.), *tamariscus* (Nich.), *ovatus* (Barr.), and *palmeus* (Barr.). The first two are by far the most numerous.

The upper limit of the Llandovery Beds appears to be well defined by the hard gritty band occurring at the base of No. 7.

8. *Fossiliferous Band.*—This differs somewhat in lithological characters from the lower graptolitic bands. It is not so black, nor is it so soft, being of a more gritty nature. It yielded the following fossils:—

*Monograptus Hisingeri* (Carr.).

\* — *crispus* (Lapw.).

\* — *cf. sartorius* (Tullb.).

\* — *cf. speciosus* (Tullb.).

\* — *runcinatus* (Lapw.).

\* *Monograptus pandus* (Lapw.).

— *lobiferus* (M'Coy).

\* — *cf. nodifer* (Tullb.).

*Diplograptus Hughesii* (Nich.).

*Climacograptus normalis* (Lapw.).

It is this fauna which leads us to believe that the zone is a passage-zone, as the fossils marked with an asterisk are characteristic Tarannon forms, while the other species are common in the Llandovery Beds.

## 2. The Tarannon Shales.

(a) *Marsh-section*.—Unfortunately the lowest beds of the Tarannon Shales in this district are not very fossiliferous—at least in places which are accessible, for much of the section is obscured by buildings and lumber from the adjoining timber-yard.

At the corner of the road, however, we succeeded in obtaining two slabs on which were seen a number of badly preserved *Monograptids*. Many of these were too obscure for identification, but we have determined *M. pandus* (Lapw.), *M. Hisingeri*, var. *nudus* (Lapw.), *Cyrtograptus Lapworthi* (Tullb.), and *C. (?) spiralis* (Gein.).

These beds were almost immediately faulted out against the Wenlock Shales.

(b) *Section opposite the Forge*.—The section of Tarannon Shales seen opposite the forge is by far the best in the district, and contains a rich graptolitic fauna. It was from these beds that Prof. Lapworth obtained the fossils recorded by him in his 'Distribution of the Rhabdophora' (Ann. & Mag. Nat. Hist. 1880, ser. 5, vols. v. & vi.). The strike of the beds does not appear to have been affected by the fault, and they dip 10° W. of S. at a fairly constant angle of about 55°.

The beds consist of alternations of hard grey unfossiliferous flagstones, with softer black shale-bands containing graptolites. They are quite different in character from the Llandovery rocks, and are not so fissile.

The following is the complete section seen; the lowest beds occur exactly at the corner by the forge, while higher beds come on along the road in either direction:—

	Ft. In.
13. Soil and loose shale .....	4 0.
12. Bands of hard grey flags, with softer seams. Unfossiliferous...	2 6
11. Black shale-band, with graptolites. Very ferruginous and deeply weathered .....	1 6
10. Grey flagstones .....	0 9
9. Black shale-band, with graptolites. Very soft, and stained yellow .....	1 0
8. Grey flagstones .....	0 9
7. Soft black graptolitic shale .....	0 6
6. Grey flags, with narrow band of hard yellow grit: all very ferruginous .....	0 5
5. Soft black shale, with graptolites .....	0 9
4. Unfossiliferous grey flags .....	0 7
3. Black shale, with graptolites .....	0 9½
2. Grey flags .....	1 0
1. Grey, sandy, graptolitic band; iron-stained above.	

(Base not seen.)

**Band No. 1.**—Lithologically this band differs from any of the other graptolite-bearing bands seen in this section. It may be roughly separated into two divisions:—

- (a) Lower. Sandy grey bed.  
(b) Upper. Flaggy bed, stained bright red.

In the lower of these two divisions the graptolites are very numerous but fragmentary, and for the most part very badly preserved; those in the upper division are more easily determinable. We obtained the following fossils:—

<i>Monograptus pandus</i> (Lapw.). C.	<i>Monograptus speciosus</i> (Tullb.).
— <i>runcinatus</i> , var. (Lapw.).	— <i>crispus</i> (Lapw.).
— <i>exiguus</i> (Nich.). C.	— <i>turriculatus</i> (Barr.).
— <i>nodifer</i> (Tullb.).	— <i>Becki</i> (Barr.)?
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.).	— ? <i>urceolus</i> (Richter).
— —, var. <i>jaculum</i> (Lapw.).	<i>Petalograptus palmeus</i> (Barr.).
— <i>broughtonensis</i> (Nich.).	<i>Diplograptus tamariscus</i> (Nich.).

The unfossiliferous flagstones are very similar throughout; they consist of pale grey flaggy beds, occasionally somewhat gritty, and are often very hard. Some of the upper beds are speckled.

**Band No. 3.**—This soft mudstone-band has yielded the following forms:—

<i>Monograptus pandus</i> (Lapw.).	<i>Monograptus</i> ? <i>urceolus</i> (Richter).
— <i>runcinatus</i> , var. (Lapw.).	— cf. <i>flexuosus</i> (Tullb.).
— <i>exiguus</i> (Nich.). C.	— <i>capillaceus</i> (Tullb.).
— <i>turriculatus</i> (Barr.). C.	<i>Petalograptus palmeus</i> (Barr.).
— cf. <i>cygneus</i> (Törnq.).	

**Band No. 5.**—From this band we have identified

<i>Monograptus turriculatus</i> (Barr.).	<i>Monograptus galaensis</i> (Lapw.).
— <i>pandus</i> (Lapw.).	— <i>Flemingii</i> (Salter).
— <i>runcinatus</i> , var. (Lapw.).	— ? <i>urceolus</i> (Richter).
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.).	— <i>Proteus</i> (Barr.).
— <i>exiguus</i> (Nich.).	<i>Petalograptus palmeus</i> (Barr.).
— <i>crispus</i> ? (Lapw.).	— <i>ovatus</i> (Barr.).

**Band No. 7.**—This contains

<i>Monograptus turriculatus</i> (Barr.). C.	<i>Monograptus speciosus</i> (Tullb.).
— <i>exiguus</i> (Nich.).	— <i>retroflexus</i> ? (Tullb.).
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.).	<i>Diplograptus tamariscus</i> (Nich.).
— <i>pandus</i> (Lapw.).	

**Band No. 9.**—This bed is peculiar, because of its being stained bright yellow; it has yielded

<i>Monograptus pandus</i> (Lapw.).	<i>Monograptus Hisingeri</i> , var. <i>jaculum</i>
— <i>turriculatus</i> (Barr.).	(Lapw.).
— <i>crispus</i> (Lapw.).	<i>Petalograptus ovatus</i> (Barr.)? C.
— <i>exiguus</i> (Nich.).	— <i>palmeus</i> (Barr.). C.
— <i>priodon</i> (Bronn).	<i>Retiolites Geintzianus</i> (Barr.).
— <i>Hisingeri</i> , var. <i>nudus</i> ? (Lapw.).	

**Band No. 11.** This band consists of black flaggy mudstones, deeply weathered and often iron-stained. It breaks characteristically into

lath-shaped fragments with a splintery fracture. We have obtained from it the following :—

<i>Monograptus pandus</i> (Lapw.). C.	<i>Monograptus speciosus</i> (Tullb.).
— <i>runcinatus</i> , var. (Lapw.). C.	— cf. <i>cygneus</i> (Törnq.).
— <i>exiguus</i> (Nich.). C.	— <i>priodon</i> (Bronn.).
— <i>attenuatus</i> (Hopk.).	— <i>concinus</i> (?), Lapw.
— <i>crispus</i> (Lapw.).	— ? <i>urceolus</i> (Richter).
— <i>broughtonensis</i> (Nich.).	<i>Petalograptus ovatus</i> (Barr.).
— <i>turriculatus</i> (Barr.). C.	— <i>palmeus</i> (Barr.). C.
— <i>riccartonensis</i> (Lapw.).	<i>Diplograptus tamariscus</i> (Nich.).
—, sp. nov.	— <i>Hughesii</i> (Nich.).
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.).	<i>Retiolites Geinitzianus</i> (Barr.).
—, var. <i>jaculum</i> (Lapw.).	— <i>obesus</i> (Lapw.).
— <i>galaensis</i> (Lapw.).	

Strictly speaking, this band might be divided as follows :—

- (a) Graptolitic Shale.
- (b) Unfossiliferous Flags.
- (c) Graptolitic Shale.

But (b) is of such insignificant thickness that for practical purposes it seems better to group the three as one bed.

It will be evident from these lists that several species of graptolites are common to all the bands: for example, *Monograptus exiguus* (Nich.) and *M. turriculatus* (Barr.) range throughout, and have been found on the same slab; *M. pandus*, Lapw., and *M. runcinatus* var., Lapw., are also commonly associated with these.

(c) *Shore-section*.—The only other place where we found a workable section was that seen at low tide on the shore between the timber-yard and the lodge belonging to the Benarth Lunatic Asylum. The section commenced just at the old landing-stage.

The dip and strike remain constant as before, but, owing to the fact that beds are denuded along their dip, they are exposed somewhat farther to the south than is the case in the road. Unfortunately, where we hoped to find the highest beds the section was obscured by sand and shingle, and the rocks next visible were certainly of Wenlock age, since they contained *Monograptus priodon* (Bronn), *M. vomerinus* (Nich.), etc.

We believe that there is a continuous outcrop of Tarannon Shales from the fault (F. 2) to F. 1, the boundary-fault; but there are no good exposures, as the ground is chiefly a grassy slope. The presence of these beds was therefore in most cases inferred by the disappearance of the feature invariably formed by the Wenlock Shales.

### 3. The Wenlock Shales.

A considerable thickness of Wenlock Shale underlies the lowest band of Denbighshire Grit in this district. The outcrop assumes a curious form to the west, owing to the presence of the fault (F. 1) and to the configuration of the ground.

Lithologically, the beds differ markedly from the underlying

Tarannon Shales; they are generally harder, of a lighter, often speckled colour, and in places very shivery. The fossils are fairly well preserved, but, owing to the direction of the cleavage, are often difficult to obtain. The beds change their strike somewhat as they approach the faults, being in each case bent up towards them; this is especially well marked in the case of the fault which forms the boundary of the Silurian rocks to the west. We were fortunate in having several workable exposures on the hillside, and these we will proceed to describe in some detail.

(i.) Sections West of Fault (F. 2).

(a) *Section S.W. of Rose Mill Farm.*—The sections exposed near Rose Mill Farm are of small extent. They are chiefly interesting as showing the alteration in the strike of the beds as these approach the fault. Here the strike is  $20^{\circ}$  N. of W., while as a general rule it is  $10^{\circ}$  N. of W. The fossils here are for the most part but poorly preserved, but we have identified *Monograptus personatus*, Tullb., *M. vomerinus*, Nich., *M. broughtonensis* (Nich.), and *Cyrtograptus Murchisoni*, Carr. At Rose Mill Farm itself the shales are very shivery, and from the nature of the rock no fossils were obtainable. Here and south of the farm the strike is  $15^{\circ}$  N. of W.

(b) *Neckarmount.*—An exceedingly good section is exposed along the rough cart-track which leads up from the road, past Neckarmount House, to the farm.

The beds appear to come on about 160 yards above Gyffin Road; they dip steadily into the hill to the S.S.W. at a high angle of about  $50^{\circ}$ , and maintain a constant strike  $10^{\circ}$  N. of W. The shales do not appear to be equally fossiliferous throughout. In some bands graptolites are abundant, while others appear to be quite unfossiliferous. The fossiliferous bands yielded *Monograptus priodon*, Bronn, *M. vomerinus*, Nich., *M. personatus*, Tullb., *M. flexuosus*, Tullb., *M. Hisingeri*, var. *rigidus* (?), Lapw., and *Cyrtograptus* sp.

East of Neckarmount the harder unfossiliferous bands are exposed, at the top of a sudden rise of ground. Here the direction of strike changes to  $20^{\circ}$  N. of W. This is evidently due to the presence of the fault (F. 2), which is at this place in close proximity.

(ii.) Sections East of Fault (F. 2).

(a) *Road-section.*—As mentioned above, the Wenlock Shales are faulted against the Tarannon Shales to the west. Unfortunately the beds here are so deeply weathered that fossils are exceedingly rare, but the change in the character of the rocks, in addition to palæontological evidence, enables us to affirm with some certainty that the beds are of Wenlock age. The only graptolites obtainable were *Monograptus vomerinus*, Nich. (1 specimen), *M. flexuosus*, Tullb. (1 specimen), and *Cyrtograptus* ? (1 specimen).

(β) *Hillside-sections*.—On the hillside, immediately above, the exposures yielded several graptolites, belonging, however, to but few species: *Monograptus priodon*, Bronn, *M. personatus*, Tullb., *M. vomerinus*, Nich., and *M. flexuosus*, Tullb.

This exposure was traceable, with interruptions, round the hill to above the lodge leading to Benarth Asylum.

(γ) *Shore-section*.—The section of Wenlock Shales exposed on the shore at low tide is very complete. These beds first appear just below the end of the lodge garden, and continue for some distance along the shore. The lower beds are very shivery in character, but as higher beds are reached they become more compact and finally pass up into the hard flagstones with intercalated grit-bands belonging to the series of Denbighshire Grits and Flags. The following fossils were obtained :—*Monograptus priodon*, Bronn; *M. personatus*, Tullb.; *M. vomerinus*, Nich.

#### 4. The Denbighshire Grits and Flags.

The boundary-line between the Wenlock Shales and the Denbighshire Grits and Flags east of the fault (F. 2) is approximately correct; but between this fault and the western limit exposures are rare, and the boundary cannot be fixed with any accuracy. Quite near the western fault exposures are more abundant, and the alteration of strike near the line of disturbance is perfectly evident.

### V. CORRELATION WITH OTHER AREAS.

#### 1. The Llandovery Rocks.

The general character of the graptolites found on the bank of the stream and in the road-section shows that the beds are nearly related to the Upper Birkhill Shales of Southern Scotland, and also to similar beds occurring in the Lake District and elsewhere.

We do not think that it is possible to trace at Conway all the minuter subdivisions recognized at Moffat, but certainly our highest band (No. 6 of the stream-section) corresponds with the uppermost zone of the Birkhill Shales, namely with the zone of *Rastrites maximus*. The bands below (Nos. 2 and 4) may subsequently be found to be the equivalents of lower zones, but in the present state of our knowledge it is wisest to say only that the beds contain an Upper Birkhill fauna. The following table shows the species common to the beds in various areas :—

CONWAY.	SCOTLAND.		LAKE DISTRICT.		CENTRAL WALES.
Llandovery Beds.	Zone of <i>Rastrites maximus</i> .	Upper Birkhill.	Middle Skelgill.	Upper Skelgill.	
* <i>Rastrites maximus</i> (Carr.).....	*	*	.....	*	*
— <i>gemmatus</i> (Barr.) .....	.....	.....	*	.....	.....
* — <i>distans</i> (Lapw.).....	*	*	.....	.....	.....
— <i>peregrinus</i> (Barr.).....	*	*	*	.....	*
* <i>Monograptus argutus</i> (Lapw.) ..	.....	*	*	.....	.....
— <i>Barrandii</i> (Tullb.) .....	.....	.....	.....	.....	.....
* — <i>concinus</i> (Lapw.).....	*	*	*	.....	.....
* — <i>cyphus</i> (Lapw.) .....	.....	*	*	.....	.....
— <i>crassus</i> (Lapw.) .....	*	*	.....	*	.....
* — <i>gregarius</i> (Lapw.).....	*	*	*	*	.....
— <i>galaensis</i> (Lapw.) .....	*	*	.....	.....	.....
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.) ..	.....	.....	.....	.....	.....
— <i>involutus</i> (Lapw.) .....	*	*	*	*	*
* — <i>lobiferus</i> (M'Coy) .....	*	*	*	.....	*
— <i>runcinatus</i> (Lapw.) .....	.....	*	.....	*	*
* — <i>spinigerus</i> (Nich.) .....	*	*	.....	.....	.....
* — <i>turriculatus</i> (Barr.) .....	*	*	.....	*	*
<i>Petalograptus ovatus</i> (Barr.) ..	*	*	.....	.....	.....
* <i>Diplograptus Hughesii</i> (Nich.) ...	*	*	*	*	.....
* — <i>palmeus</i> (Barr.) .....	*	*	.....	*	.....
— <i>sinuatus</i> (Nich.).....	*	*	*	*	.....
* — <i>tamariscus</i> (Nich.).....	*	*	*	*	.....
* <i>Climacograptus normalis</i> (Lapw.)	*	*	*	*	.....

As shown by this table, the correspondence between the fauna of the Conway beds and that of the Upper Birkhill Shales is very close. As the study of our fossil lists will show, the species are by no means evenly distributed throughout the three bands.

Some forms, which are very rare in the zone of *Rastrites maximus*, are far more characteristic of the Tarannon Shales; such, for instance, as *Monograptus turriculatus*, *M. galaensis*, *M. pandus*, and *M. Barrandii*. Others occur more abundantly in the lower bands (2 and 4), and may indicate the presence of lower zones. *Monograptus gregarius* is fairly common in band No. 2, but we have succeeded in obtaining only one specimen from the zone of *Rastrites maximus*.

*Rastrites peregrinus* was found only in the lowest band (No. 2). The poverty of the fauna from this lowest band was no doubt in part due to the very small extent of the exposure; had we been enabled to work it better, we probably should have found it possible to definitely determine its age.

## 2. The Tarannon Shales.

The correlation of the lowest fossiliferous band of the Tarannon Group is a matter of some difficulty. We did not succeed in finding

*Monograptus turriculatus*; but the fauna, on the whole, shows affinities with the underlying and overlying beds, and we therefore consider that it is of the nature of a passage-bed. We do not know its exact equivalent in other areas.

The main mass of the Tarannon Shales may be correlated with the lower of the two groups into which Prof. Lapworth (Ann. & Mag. Nat. Hist. ser. 5, vols. v. & vi. 1880) has divided the Gala rocks of the Southern Uplands of Scotland—that is, the zone of *Monograptus exiguus*.

It does not seem possible to recognize here the two sub-zones defined by Messrs. Marr and Nicholson (Quart. Journ. Geol. Soc. vol. xlv. 1888, p. 654) in the Lake District. There they found (1) zone of *Monograptus turriculatus* (Barr.) and (2) zone of *M. crispus* (Lapw.). In our beds *M. turriculatus* and *M. exiguus* range together throughout, but it is noticeable that the genus *Retiolites* is confined to the uppermost members of the series.

The following table shows the relation of the Tarannon Shales of Conway to beds of similar age in the Lake District and Southern Scotland:—

CONWAY.	LAKE DISTRICT.	SOUTH SCOTLAND.
Tarannon Shales.	Browgill Shales.	Lower Gala.
* <i>Monograptus Becki</i> (Barr.) .....	.....	*
— <i>broughtonensis</i> (Nich.) .....	*	.....
* — <i>crispus</i> (Lapw.) .....	*	*
— <i>concinnus</i> (Lapw.) .....	.....	*
* — <i>exiguus</i> (Nich.) .....	*	*
— <i>Flemingii</i> (Salt.) .....	.....	*
— <i>galaensis</i> (Lapw.) .....	.....	*
— <i>Hisingeri</i> , var. <i>nudus</i> (Lapw.) .....	*	*
— <i>priodon</i> (Bronn) .....	.....	*
* — <i>pandus</i> (Lapw.) .....	*	.....
— <i>runcinatus</i> , var. (Lapw.) .....	.....	*
* <i>Cyrtograptus spiralis</i> (Gein.) ..	*	.....
<i>Petalograptus ovatus</i> (His.) .....	.....	*
— <i>palmeus</i> (Barr.) .....	*	*
<i>Diplograptus tamariscus</i> (Nich.) .....	.....	*
* <i>Retiolites Geinitzianus</i> (Barr.) ...	*	.....
* — <i>obesus</i> (Lapw.) .....	*	*

It is interesting to note that several of the graptolites found in the Tarannon Shales of Conway seem to be identical with many Swedish forms of the same age.

### 3. The Wenlock Shales.

The correlation of these beds is matter of no difficulty; they seem to be the equivalents of the Pen-y-glog Slates of the Dee Valley



(Lake, Quart. Journ. Geol. Soc. vol. li. 1895, p. 9), the Brathay Flags of the Lake District (Marr, Geol. Mag. 1892, p. 535), and the Riccarton Flags of Scotland.

CONWAY.	DEE VALLEY.	LAKE DISTRICT.	SCOTLAND.
Wenlock Shale.	Pen-y-glog Slates.	Brathay Flags.	Riccarton Beds.
<i>Monograptus priodon</i> (Bronn).	*	*	*
— <i>vomerinus</i> , Nich. ....	*	*	*
— <i>personatus</i> (Tullb.).....	*	*	...
<i>Cyrtograptus Murchisoni</i> (Carr.)	*	*	...

There also occurs at Conway *Monograptus flexuosus*, which is a Swedish form of Wenlock Shale age.

#### 4. The Denbighshire Grits and Flags.

The Denbighshire Grits and Flags, from their position above the Wenlock Shales, are in all probability the equivalents of the beds overlying the Pen-y-glog Slates in the Dee Valley, which Mr. Lake has shown (*op. cit.*) to be of Lower Ludlow age.

#### *Approximate Correlation of Beds.*

CONWAY.	CENTRAL WALES AND WESTERN ENGLAND.	LAKE DISTRICT.	SCOTLAND.
Denbighshire Grits and Flags.	Denbighshire Grits and Flags. { Nant-Glyn Flags, Moel-Ferna Slates, and Pen-y-glog Grit.	Coldwell Beds.	
Wenlock Shales.	Wenlock Shales (Pen-y-glog Slate).	Brathay Flags.	Riccarton Flags.
(Upper beds absent.) Tarannon Shales.	1. Zone of <i>Retiolites Geinitzianus</i> , <i>C. Grayæ</i> . 2. Zone of <i>Monograptus turriculatus</i> , <i>M. exiguus</i> , etc.	Upper Browgill Beds. Lower Browgill Beds.	Upper Gala Beds. Lower Gala Beds.
Upper Llandovery Beds.	Llandovery Beds of Cardigan and Dee Valley.	Upper Skelgill Shales.	Upper Birkhill Shales.

## VI. GENERAL CONCLUSIONS.

From the facts brought forward in the present paper it is evident that rocks of Llandovery age do occur in North Wales, and hence that the stratigraphical break in that region between the Silurian and Ordovician rocks is, at any rate, far less actually than has hitherto been supposed.

The type of Llandovery rocks developed at Conway is more closely related to that of Southern Scotland and Northern England than to that of the typical Welsh Borderland area, and it is interesting to observe that here, at any rate, deep-water conditions prevailed from Upper Llandovery to Wenlock times.

With regard to the Tarannon Shales, Wenlock Shales, and Denbighshire Grits and Flags, they differ in no essential respect from those found in the Dee Valley, which have been recently shown (Lake, Quart. Journ. Geol. Soc. vol. li. 1895, *op. cit.*) to be the normal type, and therefore require no further comment.

Our best thanks are due to Mr. J. E. Marr, F.R.S., and Prof. Charles Lapworth, F.R.S., for much kind help and assistance in our work.

## DISCUSSION.

The PRESIDENT said that the Authors of this paper had made an exhaustive survey of a limited area, collecting the fossils and correlating with care the graptolites from each horizon. Such work deserved the Society's praise, as following the example of Prof. Lapworth and other careful workers. Such accurate field-work, coupled with careful palæontological results, was of the greatest value.

Dr. HICKS said that he had listened with much interest to the paper, and he hoped the Authors would continue their researches into other areas in North Wales, for it is highly important that the fossil-zones in the beds forming the base of the Silurian in that area should be clearly defined. He had not examined the sections referred to by the Authors, but some years ago he found that the sandstones on the eastern side of the Conway valley (towards Llanrwst) contained *Nematophycus* and other fossils characteristic of the Pen-y-glog Beds near Corwen. He would have liked to hear whether the Authors considered that the deep-water beds of Upper Llandovery age at Conway rested directly on the Bala Beds, and whether there was an entire absence of the beds near Bala classed by Mr. Ruddy as Lower Llandovery.

Mr. W. W. WATTS congratulated the Authors on a most admirable piece of work. He pointed out how the Upper Llandovery rocks had been gradually recognized and extended. There was no gap between those of Shropshire and of Conway, for the rocks had been recognized on the Breiddens, near Meifod in Montgomeryshire, and in the Berwyns. There appeared to be no evidence of conformity between the Ordovician and Silurian rocks in the Conway district, in spite of the fact that somewhat deep-sea beds had been found there. He hoped that the Authors would recognize the *Monograptus colonus*- and *M. leintwardinensis*-beds in the Denbighshire Grit.

15. EVIDENCES of GLACIAL ACTION in AUSTRALIA in PERMO-CARBONIFEROUS TIME. By T. W. EDGEWORTH DAVID, Esq., B.A., F.G.S., Professor of Geology in the University of Sydney. (Read February 5th, 1896.)

## [PLATE XII.]

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THE subject of which this paper treats has already been traversed by the author in his Presidential address to the Geological Section of the Australasian Association for the Advancement of Science, at its meeting at Brisbane in January 1895.

The author hopes, however, that the presentation to this Society of a summary of these previous records,—with the addition of his subsequent field-work in 1895,—will be justified by the opportunity now given of a discussion which will be of immense benefit in furthering an important and interesting branch of geological investigation.

The personal observations recorded in this paper are the result of 13 years', more or less constant, field-work in Australia.

## I. WORK DONE BY PREVIOUS OBSERVERS.

The first actual record of evidence of ice-action in Australia is probably that made by Dr. A. R. C. Selwyn in 1859.<sup>1</sup>

The statement is as follows:—‘At one point in the bed of the Inman I observed a smooth, striated, and grooved rock-surface presenting every indication of glacial action. The bank of the creek showed a section of clay and coarse gravel, or drift, composed of fragments of all sizes irregularly interbedded through the clay. The direction of the grooves and scratches is E. and W. in parallel lines; and though they follow the course of the stream, I do not think they could have been produced by the action of water forcing pebbles and boulders detached from the drift along the bed of the stream. This is the first and only instance of the kind I have met with in Australia, and it at once attracted my attention, strongly reminding me of the similar markings I had so frequently observed in the mountain-valleys of North Wales.’

These very important observations appear to have been lost sight

<sup>1</sup> ‘Geological Notes of a Journey in South Australia from Cape Jarvis to Mount Serle,’ by A. R. C. Selwyn, Parliamentary Paper, no. 20, Adelaide, 1859, p. 4.

of for about 35 years, and Australian geologists have not yet had an opportunity of confirming them; but the subsequent discoveries in this neighbourhood by Prof. Ralph Tate, of Adelaide University, leave no doubt as to their accuracy.

In 1860 the Rev. W. B. Clarke<sup>1</sup> recorded the existence of a few 'blocs perchés' in the Australian Alps.

In 1866 Sir Richard Daintree<sup>2</sup> recorded evidences of ice-action in the districts of Bacchus Marsh and Ballan, in Victoria, in these words:—'Here [on the Lerderberg River, Bacchus Marsh, Victoria] I have found a few pebbles grooved in the manner I have read of as caused by glacial action.'

This observation has been confirmed by several geological workers, including the present author; and glaciated boulders from near this locality were exhibited at the meeting when this paper was read.

In 1877 Prof. Ralph Tate<sup>3</sup> discovered a glaciated rock-pavement capped by glacial beds at Hallett's Cove, near Adelaide, and on May 7th of that year he recorded his discovery in a course of public lectures. The glaciated rock-pavement is described as being of Archæan age and as forming the summit of the sea-cliffs for a distance of about a mile in a N. and S. direction, with a width of a few yards, and as terminating inland against a low mural escarpment of Miocene limestone. Recent observations by Mr. A. W. Howchin, Prof. Ralph Tate, and the author, show that this pavement extends for at least  $\frac{1}{4}$  mile under the Miocene limestone. The glacial beds which intervene between the pavement and the Miocene limestone are stated to contain blocks of rock derived from an area about 35 miles to the south. The pavement is described as being smoothed and striated in a north-and-south direction, and as showing evidence that the ice which caused the striation came from the south.

In 1879 Mr. R. L. Jack<sup>4</sup> recorded his discovery of blocks of granite, slate, etc., contemporaneously embedded in strata of Permian-Carboniferous age, in the Bowen River Coalfield, Queensland. The presence of these blocks is attributed by Mr. Jack to the action of floating ice.

In 1879 the late Mr. C. S. Wilkinson<sup>5</sup> recorded what he considered to be evidence of glacial action in the Triassic Hawkesbury Series of New South Wales. This evidence consists of disrupted masses of clay-shale, of all sizes up to 20 feet in diameter, embedded in sandstone.

<sup>1</sup> 'Researches in the Southern Goldfields of New South Wales,' Sydney, 1860, p. 225.

<sup>2</sup> Geological Survey of Victoria. 'Report on the Geology of the District of Ballan, including Remarks on the Age and Origin of Gold, etc.' By Richard Daintree. Melbourne, 1866.

<sup>3</sup> See Rep. Austr. Assoc. Adv. Science, vol. i. pp. 231-232, Sydney, 1887; *ibid.* vol. v. p. 31, Adelaide, 1893; also Trans. Roy. Soc. S. Austr. vol. ii. 1879, p. lxiv.

<sup>4</sup> 'Report on the Bowen River Coalfield,' by Robert L. Jack, p. 7, par. 39. Brisbane, 1879.

<sup>5</sup> Journ. Roy. Soc. N. S. Wales, vol. xiii. 1879, 'Notes on the Occurrence of remarkable Boulders in the Hawkesbury Rocks,' pp. 105-107.

In 1884 Mr. R. M. Johnston<sup>1</sup> of Tasmania described the occurrence of erratics, some over a ton in weight, in the Permo-Carboniferous rocks of Maria Island, Tasmania.

In 1885 Mr. R. D. Oldham<sup>2</sup> visited Branxton in New South Wales (where Mr. C. S. Wilkinson had the previous year discovered some large erratics), and found one small boulder which he described as being unmistakably striated and polished by ice. This deposit is of Permo-Carboniferous age, and probably homotaxial with the erratic-beds of the Bowen River Coalfield, Queensland, and those of similar age in Tasmania. Mr. Oldham correlates the Branxton beds with those of Bacchus Marsh in Victoria, and suggests that they may be the equivalents of the Talchirs of India. He also suggests that during the deposition of these beds 'there was a widespread glacial epoch corresponding to that which is known to have occurred in post-Tertiary time.'

In 1886 Mr. R. M. Johnston<sup>3</sup> recorded further evidence of erratics in Permo-Carboniferous rocks at One Tree Point, Bruni Island, Tasmania. They are embedded in marine strata with which is associated *Gangamopteris spathulata*, McCoy.

In 1887 the author<sup>4</sup> recorded the occurrence of numerous erratics in Permo-Carboniferous strata at Grasstree in New South Wales.

They are mostly rounded, seldom angular; none observed were distinctly glaciated, though many were faintly striated, possibly through earth-movements. About the same time the author observed, near Branxton, a block of granite nearly a ton in weight, embedded in the Permo-Carboniferous strata in such a position as to leave no other explanation possible than that it had been dropped from floating ice. (A photograph of this was exhibited at the meeting.)

In 1890 the late Dr. Feistmantel<sup>5</sup> correlated the Bacchus Marsh Beds of Victoria and the Upper and Lower Marine Beds of New South Wales with the Dwyka Conglomerates of Southern Africa, and with the Talchir Boulder-beds of India. The *Productus*-limestone which in the Salt Range caps the Talchir Boulder-beds afforded palæontological evidence for the above correlation.

Feistmantel summarizes the evidence as follows:—'This circumstance [the occurrence of ice-scratched boulders in the strata] would, of course, indicate a rather general change of climatic conditions over Australia, portions of Africa, India, etc. towards the close of the Carboniferous epoch. But I do not think that it was contemporaneous over that whole region, and it appears to me that it set in first in Eastern Australia (New South Wales), destroying

<sup>1</sup> Proc. Roy. Soc. Tasmania, 1884, p. lxxv.

<sup>2</sup> Rec. Geol. Surv. India, vol. xix. pt. i. p. 44.

<sup>3</sup> Proc. Roy. Soc. Tasmania, 1886, pp. 23-24.

<sup>4</sup> 'Evidence of Glacial Action in the Carboniferous and Hawkesbury Series in N. S. Wales,' Quart. Journ. Geol. Soc. vol. xliii. pp. 190-196.

<sup>5</sup> 'The Geological and Palæontological Relations of the Coal- and Plant-bearing Beds of Palæozoic and Mesozoic Age in E. Australia and Tasmania,' Mem. Geol. Surv. N. S. W. Pal. No. 3, pp. 46, 47, 181.

the Carboniferous flora at an early date, while in Southern Africa we find still a Carboniferous or Coal-Measure flora of a higher stage, and only hereafter the change of climate appears to have taken place there. When the conditions of ice-action ceased, there appeared in Africa, India, Victoria, New South Wales, etc., a luxuriant flora of a peculiar character, which was, however, foreshadowed by a few forms in the Lower Coal Measures in New South Wales. In this period falls the deposition of the Karoo Formation in Africa, the Gondwana System in India, the Newcastle Beds, etc., in New South Wales, the Bacchus Marsh Beds in Victoria, and so on.'

In 1890 Mr. E. J. Dunn<sup>1</sup> published a very important paper on the glacial conglomerates of Victoria. He showed that they were widely distributed on either side of the Main Dividing Range of Victoria, Wild Duck Creek near Heathcote to the north, and Bacchus Marsh to the south, being the principal localities. He described the glacial conglomerates as consisting of fragments of rock up to 30 tons in weight, mostly well rounded, frequently polished, strongly striated, grooved and faceted, more rarely angular, embedded in a groundmass of a prevailing dark grey colour. The rocks constituting the boulders are stated to be for the most part foreign to the district. Mr. Dunn says (*op. cit.* p. 456), 'No other conclusion can be arrived at than that floating ice has been the agent by which the material has been brought into its present position . . . Tasmania may have furnished some of them' [*i. e.* the erratics].

In 1891 Mr. G. B. Pritchard<sup>2</sup> recorded the occurrence of glaciated rock-surfaces at a spot to the north of the township of Curramulka, on the eastern side of Yorke Peninsula, South Australia. This evidence can be confidently correlated with that previously discovered by Prof. Ralph Tate at Hallett's Cove.

In 1892 Mr. E. J. Dunn<sup>3</sup> published another important and well-illustrated report relating specially to the glacial deposits of Wild Duck Creek. Mr. Dunn recorded therein his discovery of a strongly glaciated rock-surface near Wild Duck Creek, the striæ trending north and south. The altitude of the upper portion of the glacial conglomerate is stated to be about 700 feet above the sea.

In 1892 Messrs. Dunn and T. B. Moore<sup>4</sup> published evidence of a glacial conglomerate, 3000 feet above sea-level, near Zeehan in Tasmania. The included boulders were found to be beautifully striated. This formation should, in Mr. Dunn's opinion, be correlated with that of Bacchus Marsh.

In 1893 Mr. T. B. Moore<sup>5</sup> recorded the occurrence at Mount Tyndall of a glacial conglomerate, considered by him to be of

<sup>1</sup> Rep. Austr. Assoc. Adv. Science, vol. ii. pp. 452-456, Melbourne, 1890.

<sup>2</sup> Trans. Roy. Soc. South Australia, vol. xv. (1891-92) p. 182.

<sup>3</sup> 'Notes on the Glacial Conglomerate, Wild Duck Creek,' by E. J. Dunn, F.G.S.; Special Reports, Department of Mines, Victoria. Melbourne, 1892.

<sup>4</sup> Proc. Roy. Soc. Victoria, n. s. vol. vi. (1894) pp. 133-138, pl. viii.

<sup>5</sup> 'Discovery of Glaciation in the Vicinity of Mount Tyndall, in Tasmania,' by T. B. Moore, Proc. Roy. Soc. Tasmania, 1893, pp. 147-149.

the same geological age as that already referred to near Zeehan. Its altitude was estimated to be 3500 feet.

In 1893 Mr. A. Montgomery questioned the accuracy of Mr. T. B. Moore's determination of the geological age of the glacial conglomerate at Mount Tyndall as being Permo-Carboniferous, and suggested that it might be a re-distributed Permo-Carboniferous conglomerate glaciated perhaps in Tertiary time.

In 1893 Messrs. Graham Officer and L. Balfour<sup>1</sup> published an account, well illustrated, of the Bacchus Marsh conglomerates. They considered the glacial conglomerates referable to two distinct epochs, one belonging to Permo-Carboniferous, the other to Tertiary time. In a subsequent paper,<sup>2</sup> however, they withdrew their opinion as to the evidence in this neighbourhood of any Tertiary glaciation.

In September 1893 Messrs. G. Sweet and C. C. Brittlebank<sup>3</sup> published an important paper on the glacial deposits of the Bacchus Marsh district. They proved satisfactorily, in the author's opinion, that none of the glacial deposits there observable were referable to Tertiary time, but all belonged either to a late Palæozoic or early Mesozoic age. They described the glaciated rock-surfaces previously discovered by Messrs. Brittlebank and Graham Officer, quoting evidence to show that the striæ trend from S.W. towards N.E., and that the ice which produced them moved in a north-easterly direction. They estimated the thickness of the glacial beds at about 5000 feet, and determined their elevations as ranging from about 700 to 1400 feet above the sea. The sandstones near the top of the glacial series contain *Gangamopteris angustifolius*, M'Coy, *G. obliqua*, M'Coy, and *G. spathulata*, M'Coy, while in shaly sandstones on a somewhat higher horizon fragments of plants resembling *Schizoneura*, *Zeugophyllites*, etc., have been observed.<sup>4</sup>

In November 1894 Mr. T. S. Hall<sup>5</sup> contributed a note on the bibliography of the Bacchus Marsh Glacial Deposits.

In January 1895 the author submitted the report by Prof. Ralph Tate, Mr. Walter Howchin, and himself on the Evidences of Glacial Action at Hallett's Cove to the Australasian Association for the Advancement of Science. This is published in the volume for 1895 issued by the Association. On April 3rd, 1895, Mr. Walter Howchin contributed a paper on the same locality,<sup>6</sup> in which he gives a detailed account of the glacial phenomena, and arrives at provisional deductions.

<sup>1</sup> Proc. Roy. Soc. Victoria, n. s. vol. v. (1893) pp. 45-68, pls. x.-xii.

<sup>2</sup> *Ibid.* n. s. vol. vi. (1894) pp. 139-143.

<sup>3</sup> Rep. Austr. Assoc. Adv. Science, vol. v. pp. 376-389, Adelaide, 1893.

<sup>4</sup> Annual Report of the Secretary for Mines, Victoria, for the year 1893, pp. 18-19. Melbourne, 1894.

<sup>5</sup> 'The Victorian Naturalist,' Melbourne, 1894, pp. 125-128.

<sup>6</sup> Trans. Roy. Soc. South Australia, vol. xix. pt. i. pp. 61-69.

## II. LATEST OBSERVATIONS BY THE AUTHOR.

## (a) Hallett's Cove.

In December 1894 the author visited Hallett's Cove, near Adelaide, in company with Prof. Ralph Tate and Mr. A. W. Howchin, with the view of determining the question as to whether the glaciation was post-Miocene or pre-Miocene. This question had been discussed on the ground, during the meeting of the Australasian Association for the Advancement of Science at Adelaide in 1893, by Prof. Ralph Tate and a party of the members. For the purpose of finally settling the question, the Association placed the sum of £20 at the disposal of the members of their Glacial Committee, to enable them to cut a trench from the glaciated rock-pavement, across the outcropping edges of the glacial beds, up to the base of the Miocene limestone. Trenches were cut under the supervision of the above-mentioned members of the Committee, and with the permission of Mr. W. Reynell, and these excavations proved conclusively that the glaciation was pre-Miocene. These results have already been communicated by the Glacial Committee to the Australasian Association for the Advancement of Science.<sup>1</sup> Briefly summarized, the Report is as follows:—

The formations represented at Hallett's Cove are:—

1. Pre-Cambrian rocks, consisting of hard, purplish-red clay-slates with greenish bands, grey quartzites, and thin bands of siliceous limestone. The prevalent dip is W.  $10^{\circ}$  to  $20^{\circ}$  N. at from  $40^{\circ}$  to  $78^{\circ}$ . Wherever a fresh surface of these rocks has been exposed by the denudation of the overlying glacial beds, it is seen to be smooth and strongly glaciated, the striæ being sharply cut and as freshly preserved as though they had resulted from recent glacial action. Their trend is nearly north and south, and it is clear that the ice which produced them came from the south. The glaciated surface ascends to about 100 feet above sea-level, and descends to probably a considerable depth below the sea-level. The length of the glaciated surface preserved is about 1 mile, and its width about  $\frac{1}{4}$  mile.
2. Glacial Beds, consisting of reddish-brown clay-slates, sandy in places, and fairly well stratified, especially in their upper portion. Downward they pass into sandy, greyish-brown mudstones, containing well-striated boulders in abundance: the latter occur only sparingly in the upper portion of the deposit. Erratics, chiefly of porphyritic granite, and up to 8 tons in weight, are embedded in the strata at intervals. They belong chiefly to a variety of granite occurring in place (*dixit* R. Tate) at Port Victor, 35 miles south. The glacial beds are from 23 to more than 100 feet thick, descend below sea-level, and ascend to over 100 feet above the sea. No trace of any

<sup>1</sup> Rep. Austr. Assoc. Adv. Science, Brisbane, 1895.



organism has yet been met with in these beds. The matrix has evidently been derived from the wearing away of the local pre-Cambrian rocks, whereas many of the erratics are foreign to the neighbourhood.

3. Miocene limestone and Miocene (?) clays. The former is separated by a slight unconformity from the underlying glacial beds. It varies in composition from that of an arenaceous limestone to that of a calcareous sandstone, having a thickness of from 2 to 3 feet. The following are some of the marine fossils contained in it, as determined by Prof. Ralph Tate:—*Plesiastrea St.-Vincenti*, Ten. Woods, *Pecten spondylioides*, Tate, *Mytilus submenkeanus*, Tate, *Pectunculus convexus*, Tate, *Conotrochus typus* (Seguenza?). The limestone passes upward into clays, perhaps also of Miocene age, and about 60 feet in thickness.
4. Recent (?) nodular travertine, about 3 to 4 feet thick.
5. Blown sand and beach sand, resting successively on all the preceding formations.

It may be concluded that, as proved by the transport of the erratics and the grooving of the rock-pavements, the ice which produced the glaciation moved from south to north, and that it was of an age intermediate between Miocene and Pre-Cambrian. The comparatively slight induration of the glacial beds and remarkable freshness of the striæ suggest that the glaciation did not antedate the close of the Palæozoic era, as all rocks older than this in Australia are considerably indurated.

### (b) Wild Duck Creek, Derrinal, near Heathcote.

The formations here represented are:—

1. Lower Silurian (Ordovician), which in places exhibit strongly grooved polished surfaces, the trend of the grooves being from S. 5° E. towards N. 5° W.
2. Permo-Carboniferous Glacial Beds, consisting chiefly of mudstones, with erratics up to 30 tons in weight, and sandstones. Nearly all the erratics and small boulders are beautifully glaciated, being grooved, polished, and faceted. The beds have been traced by Mr. Dunn for 15½ miles in a north and south direction, and they have a width of 5 miles. They attain an elevation of about 750 feet above the sea, and have a thickness of probably at least 300 or 400 feet. Both Mr. Dunn and Mr. A. W. Howchin are of opinion that the erratics resemble the rocks of North Gippsland in Victoria, the age of which ranges from Silurian to Carboniferous. Here, as at Hallett's Cove, the glaciation of the rock-pavements shows that the ice probably came from the south. (Photographs of the glaciated Lower Silurian rock and of the large erratic known as 'The Stranger' were exhibited at the meeting.)

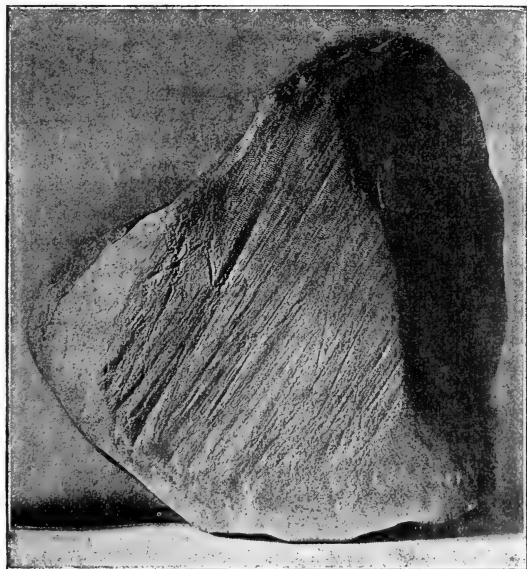
## (c) Bacchus Marsh.

This district was examined by the author in company with Messrs. G. Sweet and Charles C. Brittlebank during December 1894, and again by the author in company with Messrs. C. C. Brittlebank, T. Brittlebank, Graham Officer, and L. Balfour, during December 1895. The formations represented were as follows:—

1. Lower Silurian (Ordovician), black slates and shales, with graptolites and grey quartzites intruded in places by granite. The strike is N. 10° E. to N.E., and they dip at a high angle. Wherever their surface has been freshly exposed in this neighbourhood it is seen to be strongly grooved and polished, and more or less *moutonnée*. Such striated pavements have been traced by Messrs. Sweet and Brittlebank at intervals over an area of 130 square miles in this district; and later observations by Messrs. Officer and Balfour in the Coimadai district have proved the area to be much greater. In places where the Ordovician clay-slates have had their glaciated surface destroyed by denudation, an exquisite cast of it is preserved on the under-surface of the glacial beds, accurate impressions being retained of even the most minute striæ. The surface of the pavement is very uneven, being traversed by troughs from 500 to 600 feet deep, the slopes of the ridges separating the troughs one from another being sometimes as steep as 70°. The bottoms of the troughs and the slopes and summits of the ridges are all strongly glaciated. The author agrees with Messrs. Sweet, Brittlebank, Graham Officer, and L. Balfour in their inference that the ice which produced the glaciation came from the south. At the Werribee Gorge the striæ trend from about S. 12° W. to N. 12° E.
2. Permo-Carboniferous Glacial Beds.—The thickness of these rocks has been approximately estimated, as already stated, by Messrs. Sweet and Brittlebank to be about 5000 feet, and on the occasion of the author's first examination of them it appeared that this estimate of them was not excessive. Measurements, however, taken by Messrs. Chas. C. Brittlebank, T. Brittlebank, Graham Officer, L. Balfour, and the author last December show that the thickness may perhaps have been over-estimated through a repetition of the beds resulting from faulting or folding. Their general dip is rather steep, varying from about 15° up to 60°. They consist of:—(i) Hard and soft mudstones, from brownish-grey to light claret in colour, bluish-grey at a depth. A small proportion of fragments of undecomposed felspar is present, together with minute chips of black shale (Lower Silurian?) and small pieces of carbonized plants. The soft mudstones are chiefly composed of clayey material, with quartz-grains, mostly subangular, and contain glaciated erratics sparingly. The hard mudstones contain very numerous strongly-glaciated boulders, frequently flattened on one side as though

they had been rasped away by the ice ; their diameter varies from a few inches to  $5\frac{1}{2}$  feet, but most of them measure less than a foot in diameter. They are very firmly embedded in the matrix, so that they can be dislodged only by repeated blows from a heavy hammer. (Several fine specimens of these glaciated blocks were exhibited, including one brought by the author as a donation from Mr. C. C. Brittlebank to the British Museum. See the accompanying figure.) The

*Glaciated Boulder from the Permo-Carboniferous of Dunbar, near Bacchus Marsh, Victoria. (About  $\frac{1}{4}$  natural size.)*



[Reproduced from a photograph.]

maximum thickness of any individual bed measured proved to be 193 feet.

(ii) Conglomerates.—Greenish brown, lithologically very like those of the Permo-Carboniferous Newcastle Beds in New South Wales. They are composed of well-rolled pebbles from 1 to about 6 inches in diameter, with occasionally large glaciated erratics. The thickness of individual beds of conglomerate varies from a few feet up to about 20. In places they make a very uneven junction-line with the strata below them, as though they had been squeezed down into these so as to occupy irregularly-shaped pockets. In places the upper surface of the conglomerate is much indented, as at the elbow of Myrniong Creek, about  $\frac{1}{2}$  mile below Dunbar (the residence of Mr. Brittlebank).

(iii) Sandstones.—These vary from hard to soft, from fine to coarse, and are frequently laminated, the laminæ occasionally showing distinct evidence of contortion, especially in the neighbourhood of the irregular pockets of conglomerate. Individual beds vary in thickness from a few feet to nearly 100, being mostly about 30 feet thick. Well-preserved plant-remains are present on at least two horizons; on the lower horizon occur the three species of *Gangamopteris* already referred to, and on the higher specimens of *Zeugophyllites*, *Schizoneura*, etc. The total thickness of the glacial beds seen in the upper portion of Korkuperrimal Creek, as measured last December, proved to be 1427 feet. To this, Mr. Brittlebank estimates, a thickness of about 700 feet of strata should be added to carry the section from the top of the *Gangamopteris*-beds to the top of the strata seen above the *Schizoneura*-horizon. (The order of succession of the beds is illustrated in the accompanying horizontal and vertical sections, Pl. XII.)

The altitude of the glacial beds varies from 600 to about 1400 feet above sea-level. The source of the erratics is not known, but evidence shows that the ice which furrowed the rocks came, as already stated, from the south.

The most northerly point to which drift containing undoubtedly glaciated boulders has been traced is Springhurst, on the main railway-line between Melbourne and Sydney, at the boundary between Victoria and New South Wales.

### III. CORRELATION OF THE GLACIAL DEPOSITS.

#### (a) Australasian.

It is extremely probable that the glacial beds of Bacchus Marsh, Wild Duck Creek, and Springhurst in Victoria were of homotaxial, if not of contemporaneous origin. They may probably be correlated with the glacial conglomerates of Mount Reid and Mount Tyndall in Tasmania.

The above correlations are based chiefly on lithological evidence; there is, however, good palæontological evidence for the correlation of the Bacchus Marsh glacial beds with the erratic-bearing Permo-Carboniferous mudstones of Maria Island, One Tree Point, and Bruni Island in Tasmania, the similar beds at Maitland, Branxton, and Grasstree in New South Wales, and those of the Bowen River Coalfield in Queensland, as the genus *Gangamopteris* is distributed abundantly throughout the formations at all these localities. The glacial evidences at Hallett's Cove and at Curramulka in South Australia may safely be correlated one with another, and are very likely homotaxial with the above-mentioned glacial deposits in East Australia and Tasmania.

## (b) Extra-Australasian.

The Permo-Carboniferous glaciation of Australia and Tasmania was perhaps homotaxial with that of Southern Africa and India. In Southern Africa Mr. G. W. Stow and Dr. Sutherland have described glaciated blocks associated with the Karoo or Ecca Beds. Mr. E. J. Dunn in 1872 discovered glacial conglomerates, the Dwyka Conglomerates, at Weltevreden Farm, near the junction of the Vaal and Orange Rivers; moreover, he has told me that in 1885 he discovered a striated pavement at the junction of these rivers, and was of opinion that the movement of the ice had been from south to north. This pavement is less than 1000 feet above the sea. The shales underlying the large boulders in the conglomerate are described by him as being distinctly indented. This is in lat.  $29^{\circ}$  S., long. about  $23^{\circ} 40'$  E. Mr. Dunn has also told me that he found a specimen of *Gangamopteris* 5 inches in length in the Lower Karoo Beds above the Dwyka Conglomerates.

In India evidence of glacial action in Permo-Carboniferous time was first observed by Dr. W. T. Blanford, and subsequently similar evidence has been collected by many other observers in the Talchir Group, the Salt Range Group, the boulder-beds at Báp in Western Rajputana, and the Panjáh Conglomerates of Kashmir.<sup>1</sup>

Mr. Fedden<sup>2</sup> states that at Irai, near Chánda, the Talchir Boulder-beds rest upon compact Pem Limestones. His statement is as follows:—‘For a length of 330 yards along the river’s bank this underlying rock is exposed, displaying a large surface, polished, scratched, and grooved after the fashion so familiar to glacialists. The surface has a slope of  $12^{\circ}$ – $15^{\circ}$  to the west, obliquely overcutting the strata, which have a dip of  $8^{\circ}$  to the west-south-west. The striæ and grooves run in long parallel lines, having directions between north-east and north-north-east, oblique to the slope of the surface; and, from the manner in which the rock is affected at the edges of the few planes of jointing, it can be inferred that the movement was up the slope. . . . The actual conditions are so far confirmatory of the view we have been led to—of an ice-raft being drifted against and impelled up an opposing rock-surface. . . . It would appear that the freighted ice-mass had travelled a long distance from the south-west through the Utnúr and Edlabád (Idulabad) districts, where rocks occur of the same composition as that of the several boulders.’

The latitude of Irai is  $19^{\circ} 53'$ , elevation under 900 feet; the most southerly position of the Talchir Boulder-bed is stated to be latitude  $17^{\circ} 20'$ , and its altitude is given as only a little above the level of the sea.

Near Pokaran a similarly-glaciated pavement is stated to exhibit

<sup>1</sup> ‘Geology of India,’ 2nd ed. 1893, Stratigraphical and Structural, R. D. Oldham, pp. 120–121, 124, 135, 157–160, 198–201, etc. T. Oldham, Mem. Geol. Surv. India, vol. ix. (1872) p. 324; and W. T. Blanford, *ibid.* pp. 321–325.

<sup>2</sup> Rec. Geol. Surv. India, vol. viii. (1875) p. 17.

in addition typical *roches moutonnées* (R. D. Oldham, *op. cit.* p. 160). The marine fauna associated with the Boulder-beds of the Salt Range, and partly underlying, partly overlying them, suggests that they may be homotaxial with those of Eastern Australia and Tasmania.

This short summary of references to evidence of Permo-Carboniferous ice-action in Africa and India shows that the glacial phenomena in those regions may probably be correlated on physical and palæontological grounds with those already described as occurring in Australia, and the recent discovery of rocks of Lower Gondwana age at Bajo de Velis, in Argentina,<sup>1</sup> renders it not improbable that the evidences of glacial action which are recorded as having been observed in Brazil may be homotaxial with those of Southern Africa, India, Australia, and Tasmania.

#### IV. PROVISIONAL DEDUCTIONS.

If the correlation suggested for the Australasian glacial beds be admissible, it is probable that ice-action of some kind was taking place over a large area of the Australasian region in Permo-Carboniferous time. This region extended at least from Zeehan in Tasmania, in lat. 42° S., to the Bowen River Coalfield in Queensland, in lat. 20° 30' S., and from long. about 137° 30' E. (Curramulka) to about 151° 30' E. (Maitland). In Victoria many hundreds certainly, and probably several thousands, of square miles are still occupied by glacial beds, and it is likely that very large areas once glaciated have had all traces of glaciation effaced by denudation.

The fauna and flora associated with the Permo-Carboniferous glacial beds of Australia render it probable that these glacial beds are homotaxial with the Dwyka glacial beds of Southern Africa and the Talchir Boulder-beds of India. In the case of Australia, Southern Africa, and India, the general direction in which the ice moved appears to have been from south to north. In Australia the thickness of the glacial beds (unparalleled, so far as the author is aware, in any other part of the world, being about 2000 feet, if the intercalated beds of sandstone and conglomerate are included in the estimate) implies that the Permo-Carboniferous glacial epoch in the Southern Hemisphere was of prolonged duration. This inference is supported by the fact that in New South Wales a group of Coal Measures, over 230 feet thick, and comprising from 20 to 40 feet in thickness of coal (the Greta Coal Measures), is sandwiched in between the erratic-bearing horizon of the Lower Marine Series and the similar horizon of the Upper Marine Series.

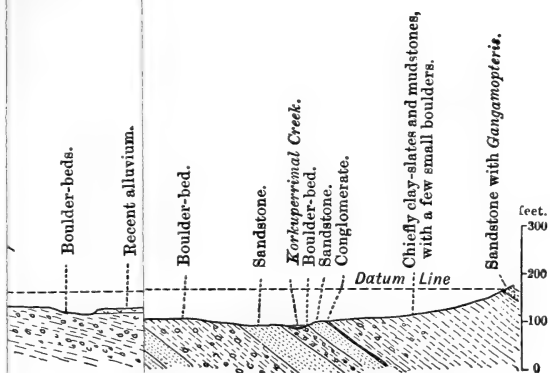
As will be seen from the vertical section accompanying this paper (Pl. XII.), there is evidence at Bacchus Marsh of at least from nine to ten distinct boulder-bed horizons, separated one from another by thick deposits of sandstone and conglomerate. The exact significance of

<sup>1</sup> Rec. Geol. Surv. Ind. vol. xxviii. pt. iii. (1895) pp. 111-117, and Revista del Museo de la Plata, vol. vi. pp. 117 *et seqq.*

ial Beds, B.

AM OFFICE (revising it).

SOUTH.

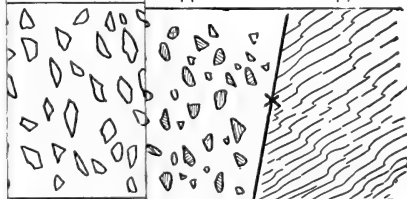


of the Perm

Hard glacial mudstones, with abundant strongly-glaciated boulders, the boulders of quartzite in particular exhibiting all the phenomena of glaciation in the highest degree of perfection: many are well faceted. The matrix in which the boulders are embedded is very hard and tough, as if it had been subjected to great pressure. The colour is yellowish-brown from the surface for about 15 feet downward, then it becomes bluish-grey.

Hard glacial mudstones, with strongly glaciated small boulders.

Lower Silurian (Ordovician) slates and quartzites, the former containing numerous graptolites, especially *Tetragraptus caduceus* and *T. fruticosus*.



193.0

195.0





Fig. 1.—Horizontal Section of Permo-Carboniferous Glacial Beds, Bacchus Marsh District (Victoria), from Cockatoo Gully southward down Korkuperrimal Creek.

Measured by T. W. EDGEWORTH DAVID, CHARLES C. BRITTLEBANK, GRAHAM OFFICER, LOUIS BALFOUR, and T. BRITTLEBANK (but the last four have not had an opportunity of revising it).

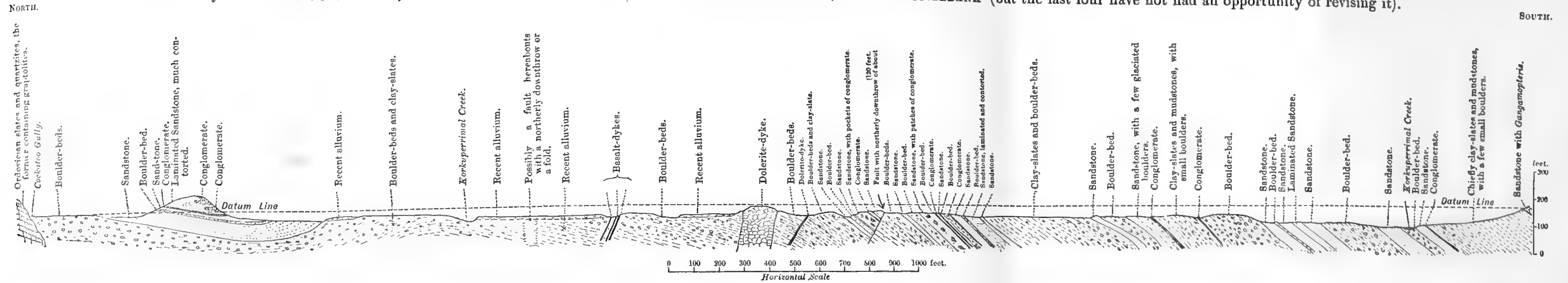
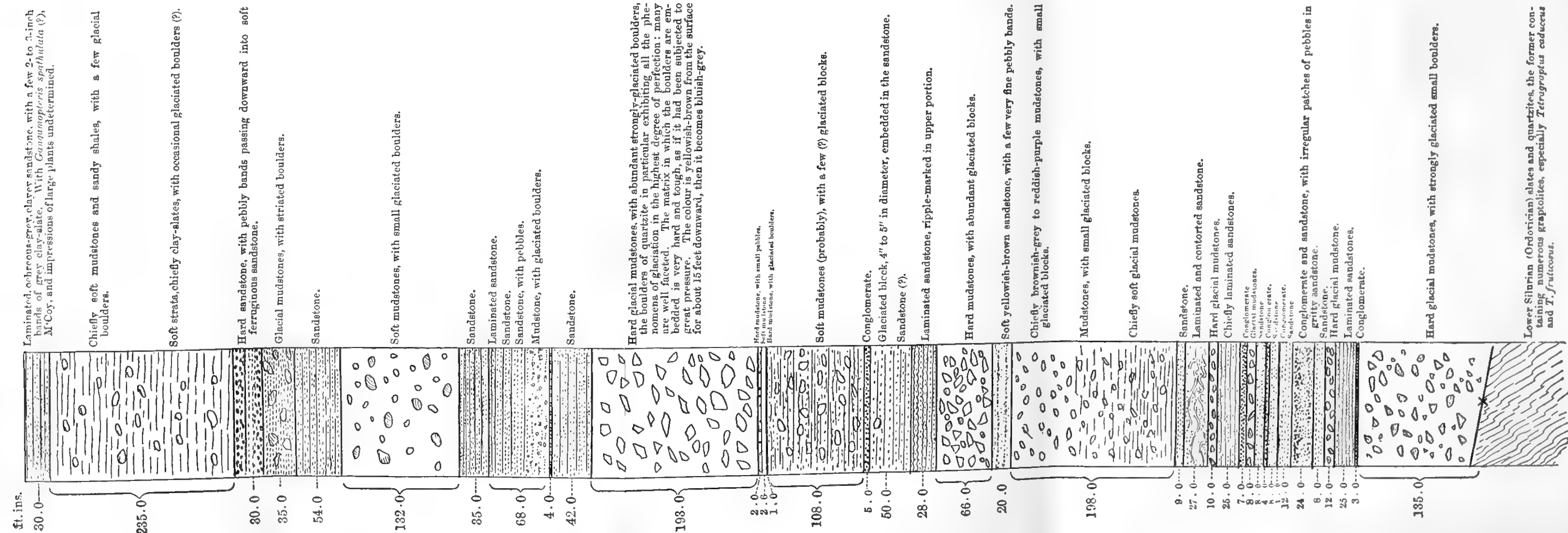


Fig. 2.—Vertical Section of the Permo-Carboniferous Glacial Beds at Bacchus Marsh (Victoria).





these lithological breaks in the succession of strata is not yet understood, but they may possibly indicate a sequence of glacial epochs separated by milder interglacial periods. Possibly glacial conditions in Australia may have been prolonged from late Palæozoic into early Mesozoic time, as may perhaps be argued from the presence of plants of Mesozoic facies, such as *Schizoneura* and *Zeugophyllites*, in the uppermost glacial beds of Bacchus Marsh, and also perhaps from the disrupted masses of clay-slates and contemporaneously-contorted current-bedding in the Triassic Hawkesbury Series of New South Wales.

#### EXPLANATION OF PLATE XII.

Horizontal and vertical sections of the Permo-Carboniferous Glacial Beds  
at Bacchus Marsh (Victoria).

#### DISCUSSION.

Dr. BLANFORD referred to the peculiar interest that he took in the paper, as he had, nearly 40 years ago, called attention to the existence in India of rocks similar to those described in Australia, and of the same age, and had suggested a glacial origin for them. He heartily congratulated the Author on his admirable paper and on the conclusive evidence of glacial action now brought forward, evidence so clear that it was doubtful whether a sceptic remained among those who had attended the meeting. The speaker proceeded to give a few details of the progress of discovery in India, and referring to the evidence gradually accumulated from Australia and South Africa, especially noticed how in the Argentine Republic of South America all the peculiar Upper Palæozoic and Mesozoic floras of Australia—the Carboniferous flora with *Lepidodendron* and *Rhacopteris*, the Permo-Carboniferous with *Glossopteris* and *Gangamopteris*, and the Lower Mesozoic with *Thinnfeldia odontopteroides*—had been discovered one after another, and how their constant associates in other lands, the boulder-beds, appear to have been found by Prof. Derby in Southern Brazil. He pointed out the connexion between these discoveries and the question of the former distribution of land, and called attention to a recent paper by Mojsisovics, Waagen, and Diener, who showed that while the present contours of the Pacific Ocean were of pre-Triassic age, those of the Indian and Atlantic Oceans appeared to be of later origin.

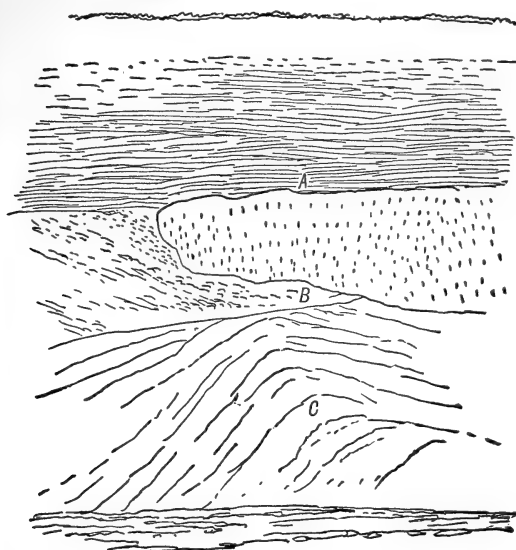
Mr. WICKHAM KING and Prof. BONNEY also spoke, and the AUTHOR replied.

16. *On TRANSPORTED BOULDER CLAY.* By the Rev. EDWIN HILL,  
M.A., F.G.S. (Read January 22nd, 1896.)

I WISH to put on record some facts lately observed respecting two groups of Boulder-Clay masses which appear to have been transported from their original positions.

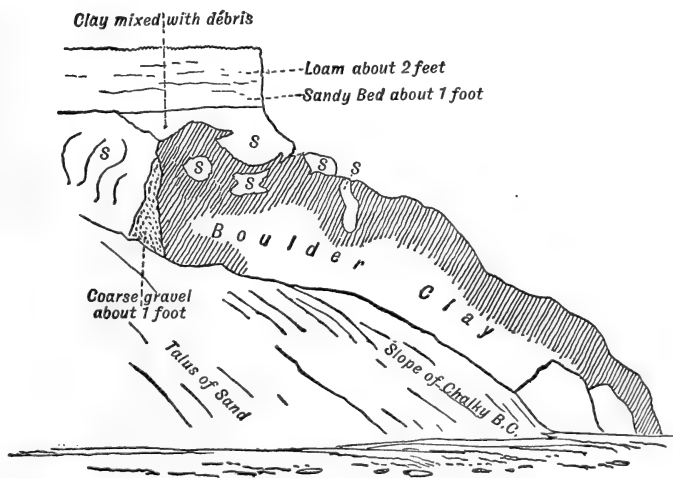
One group occurs in the cliffs south of Great Yarmouth. The sands of the cliffs which extend from Lowestoft to Yarmouth are usually described as 'Mid-Glacial.' On them lies Chalky Boulder Clay as seen at Corton and northwards, while below them are seen at several spots a perfectly different stony clay, the sands called Pebbly Sands or Westleton Beds, and the well-known Rootlet Bed. The Chalky Boulder Clay extends continuously above the Mid-Glacial sands, from Corton for about  $\frac{3}{4}$  mile northwards; farther on, one or two disconnected strips also lie on the top of the cliffs. But, besides these, several masses of the same material occur embedded in the sands. I first noticed them while examining the coast in 1893, and in the spring of 1895 I again made a careful inspection, this time in company with Prof. Bonney. Two lie one on either side of the depression called League Hole, and others were seen respectively about  $\frac{1}{2}$  mile, 1 mile, and  $1\frac{1}{2}$  mile north, towards Gorleston. The writer of the Survey Memoir (Mr. J. H. Blake) had his attention attracted to these or similar masses, and remarks that 'at times they looked as if they were lenticular patches of Boulder Clay in the Glacial Sands' (p. 56, *Geology of Country near Yarmouth and Lowestoft*). He decided, however, that 'they were all introduced after the deposition of the sands.' He does not explain how; probably he means that they had fallen from the top of the wasting cliff, and had become buried in talus or blown sand. If he had seen the sections exposed in 1893 and 1895, I think he would have concluded that they really were what he then saw that they looked like.

The mass about 2 miles south of Gorleston Pier, or  $\frac{1}{2}$  mile north of League Hole, as seen in the cliff-section, was about 4 feet thick, with 40 feet of visible length (see fig. 1). Its northern end was hidden by talus, but on the south it was seen, in a clean section of the cliff, ending abruptly against the sands, which presented their regular stratified appearance, and were in undisturbed contact with it above and below. It was normal Chalky Boulder Clay, crowded with fragments of chalk. The mass about  $1\frac{1}{2}$  mile south of Gorleston Pier had a very dark matrix, full of rather rounded chalk pieces of all sizes, from a foot long down to the finest grains; it contained also some larger inclusions of sand or silt. This mass was about 6 feet thick, also with visible stratified sands above and below. Here, too, one end was hidden under talus; the other passed into the sands in tongues and strings of dark mud, but the termination of these was again hidden by talus. The mass about 1 mile south of Gorleston was some 30 feet long; one end

Fig. 1.—Section  $\frac{1}{2}$  mile north of League Hole.

A-B = about 4 feet.      C = talus.

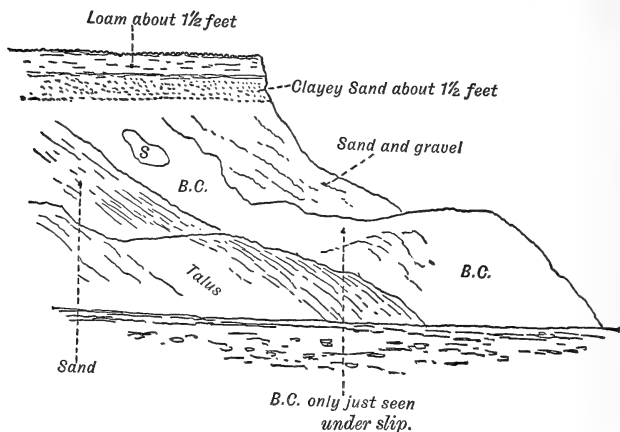
The dotted part is Boulder Clay, extending horizontally to the right for about 20 feet. Above and to the left of B, fine-bedded sand, with little lumps of Boulder Clay in it. More disturbed in the upper part.

Fig. 2.—Section immediately north of League Hole.  
(Total height = about 18 feet.)

[Looking north.]

is bent up, and both ends thin out; it is only 6 feet below the top of the cliff, and there is a layer of large flints above. In the masses at League Hole there are signs of slipping, yet here also there is sand overlying them, which I could not distinguish from the adjacent Mid-Glacial sand.<sup>1</sup> Along the beach, among the masses

Fig. 3.—Section in the little headland, near League Hole.  
(Diagrammatic.)



[Looking west.]

BC = Boulder Clay. S = Sand.

fallen from the cliff, pieces of Boulder Clay here and there occur, where none can be seen on the cliff-top; these also probably have come from the interior of the sands. The cliff is annually wasting, so that the visible sections and their appearances are in a state of constant change.

All the masses within consist of normal Chalky Boulder Clay crowded with fragments of chalk. They all pass into the sands in tongues, strings, or separate patches of a dark wet mud, like the clay of the matrix, but containing no chalk. The mass nearest Gorleston has many such streaks and patches, usually about 12 inches by 2, in the underlying sand, to a depth of about 3 feet. Even the mass first described, which, seen from the beach, seems to end abruptly, on near inspection is found to have some of these patches lying close to it in the sands. I do not see how these masses could have been formed *in situ*. The appearances agree, however, in all respects, with what would be expected if masses of Boulder Clay surrounded by ice had been floated over the waters in which the sands were being deposited, and had sunk where we find them. The

<sup>1</sup> [For figs. 1, 2, and 3 my thanks are due to Prof. Bonney, who kindly furnished them from his note-book. The sections at League Hole show that the masses terminate in the interior of the cliff as well as in its face.]

buoyancy of the ice would make the masses at first practically weightless in the water, so there would be nothing to press down the floor on which they sank. As the ice melted away they would acquire weight, but meanwhile deposition would be going on all round. As the encompassing ice melted still further, portions of the outside would break away: hence the patches. Mud also from the wet outside would ooze off and spread on the sand floor, forming the tongues and strings. In all these the chalk would have disappeared, as it has disappeared from recomposed Boulder Clay, and generally from parts where water can percolate. Meanwhile the progress of deposition would have intermixed sand with the patches, tongues, and strings in undisturbed stratification.

The other group of transported masses is different in character, date, and locality. The group came under my notice in my own parish (Cockfield, Suffolk). Here is a series of pits, containing a peculiar gravel, which I have traced along a line of about 7 miles, through the parishes of Bradfield, Stanningfield, Cockfield, and Lavenham. Their contents resemble descriptions of 'Cannon-shot Gravel': they lie at corresponding levels along the slope of an existing valley, which is hollowed out of Chalky Boulder Clay; and they probably mark an earlier water-course. They clearly indicate extensive denudation of the Boulder Clay, for the slopes of that formation rise from 40 to 60 feet above them; also the flints which it contains are clean of chalk, and have undergone considerable wear. In two of these pits, one near Cockfield 'Abbey' and one near Willow Bridge (the latter lately filled in), masses of Boulder Clay are found lying on the top of the gravel.

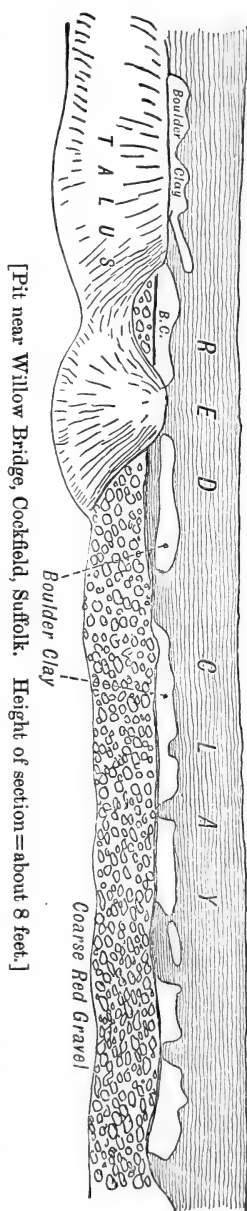


Fig. 4.—Patches of Chalky Boulder Clay in red clay, resting on coarse gravel.

In the Willow Bridge pit the clay was 2 or 3 feet thick and extended some 50 feet; whether continuously or in several adjacent masses was uncertain: appearances were in favour of the latter view, but it was difficult to decide on the nature of decomposed interruptions. The outsides and the decomposed portions are a reddish clay or earth, but the cores are perfectly normal Chalky Boulder Clay, with much chalk, in pieces from 2 or 3 inches long down to pea-size and grains.

It seems impossible to suppose that the agent which produced the Chalky Boulder Clay, after ceasing to operate during the long interval indicated by the gravels, again set up work and produced these scanty fragments. The pits described lie on the side of Boulder Clay slopes which rise, though gently, to considerably greater heights. A natural explanation is that the masses have come from higher ground, floated off or slipping down, in either case probably in a frozen state. Between them and the gravel lie seams of a finer clay, and over them something of the nature of brick-earth; while brick-earth is also abundant and worked at nearly the same level midway between the two gravel-pits named. Under the coarse gravel, in another of the pits, lie highly false-bedded white gravel and sand. Thus there is abundant evidence of contemporary water-action, and everything agrees with the view that these seams of clay have been brought, not formed *in situ*.

If these conclusions are established, some consequences follow. The writers in the Survey Memoirs on East Anglia frequently mention beds of Boulder Clay in unusual positions, intercalated in, or overlying, sands and gravels. May not many of these be also transported sheets? If so, difficulties which the writers evidently felt may be removed. Again, must not much caution be observed in attributing an 'interglacial' age to beds, fossils, or implements found beneath thin sheets of Boulder Clay, especially where this occurs also at higher elevations in the neighbourhood?

The Lowestoft instances would show that while in one locality sands, called 'Mid-Glacial,' were being deposited, in some other locality the manufacture of true Chalky Boulder Clay had already been commenced and perfected, so that exportation could go on. I do not see that they give any evidence of the process of manufacture. They are not unlike the pieces which might break off from the clay-banks of a Siberian river:—but I must not wander far into the field of conjecture.

#### DISCUSSION.

Mr. H. B. WOODWARD suggested that in Mr. Hill's Corton section the Boulder Clay might occur in the form of an intrusive tongue; and in the West Suffolk section the isolated patches of Boulder Clay might be remnants lying beneath a mass from which the chalky portions had been removed by dissolution—a feature common in the Eastern Counties.

Prof. BONNEY said that he had carefully examined the section south of Yarmouth with Mr. Hill, and could not find the slightest evidence of intrusion of the Boulder Clay—a thing, by the way, of which he



never could find evidence—but here the masses occasionally passed in strings into the sand, and small boulders of clay occurred in the sand below. Whatever might be the explanation, he could come to no other conclusion than that the clay-masses were true boulders.

Dr. DU RICHE PRELLER suggested, from the description given by the Author, that the Boulder Clay wedged in between sand, as shown in the first section, was probably deposited during an oscillation of the drift-ice, the similar effect of such oscillations being frequently apparent in the Alpine glacial deposits, which were, of course, the product of land-ice. He had recently examined some of the Boulder Clay of West Norfolk near Lynn, which was absolutely different from the glacial clay of the Alps, and, in his opinion, was clearly the product of drift-ice.

Mr. LAMPLUGH was reminded by the section on the wall of what he had seen some years ago on the flank of the Muir glacier in Alaska, where a strip of ice loaded with *débris overran* stratified gravels without disturbing them. The presence of thin strips of clayey material in gravels was a common phenomenon in Glacial deposits, and he saw no difficulty in accounting for them as the product of the edge of an ice-sheet. The admirable descriptions given by the American geologists, especially by Messrs. I. C. Russell and T. C. Chamberlin, of the great glaciers of Alaska and Greenland came as a revelation on many points to the students of glacial geology, and deserved the closest study.

The AUTHOR said that to suggest an ice-sheet as the cause of the insignificant fragments of Boulder Clay upon the gravels was like suggesting a steam-hammer as the cause where a few bits of nutshell had been found.

17. OBSERVATIONS *on the GEOLOGY of the NILE VALLEY, and on the EVIDENCE of the GREATER VOLUME of the RIVER at a FORMER PERIOD.* By Prof. EDWARD HULL, M.A., LL.D., F.R.S., F.G.S. (Read February 26th, 1896.)

## PART I.

### 1. Introductory.

THE evidence in favour of the view that the Nile was at one period a river of vastly greater volume than at the present day is so remarkable that it has forced itself on the attention of several writers, amongst whom may be specially mentioned the late Prof. Leith Adams,<sup>1</sup> Prof. Zittel,<sup>2</sup> and Capt. Lyons<sup>3</sup>; and to the statements coming from such competent observers I should hardly have thought it necessary to add any of my own, were it not that I find from personal intercourse that geographers have failed as yet to grasp the full significance of the phenomena bearing on the subject and described by the above-named authors. When about to leave for a recent visit to the Nile Valley, I wrote to Prof. (now Sir) Joseph Prestwich, enquiring whether he thought there were any problems to which a travelling geologist might give attention with some prospect of enlarging our knowledge of the physical conditions of that remarkable line of country, and in reply he recommended me to pay special attention to the terraces. This advice I endeavoured to keep before my mind during my ascent as far as the First Cataract and the return journey; and I venture to lay before the Society the impressions that I then received, and the conclusions that I have drawn from them regarding the volume and dimensions of the river at a prehistoric period. But, before entering upon this special subject, I wish to note a few points connected with the geological structure of the Nile Valley, which came under my notice, although they may not be altogether new.

### 2. Some Points in the Geology of the Nile Valley.

And first let me observe that it is only by personal examination that one can realize the extent of the erosion by old river-action which was carried on after the Libyan region had been elevated out of the waters of the sea at the close of the Eocene period. That this erosion was accomplished mainly during the succeeding Miocene

<sup>1</sup> Leith Adams, 'On the Geology of a Portion of the Nile Valley, etc., with Note on the Shells, by S. P. Woodward,' *Quart. Journ. Geol. Soc.* vol. xx. (1864) p. 6.

<sup>2</sup> Zittel, 'Beiträge zur Geologie und Paläontologie der Libyschen Wüste,' *Paläontographica*, vol. xxx. pt. i. 1883.

<sup>3</sup> Lyons, 'On the Stratigraphy and Physiography of the Libyan Desert of Egypt,' *Quart. Journ. Geol. Soc.* vol. l. (1894) p. 531.

period, upon the rising of the land, there can be little doubt; as it is becoming more clear that this was the special epoch of elevation, disturbance of strata, and denudation over all the Egyptian and Syrian region.<sup>1</sup> But there was a second period of great fluvial inundation in what may be designated 'the Pluvial period,' extending from later Pliocene times into, and including, the Pleistocene; and to this latter stage I shall have occasion to recur later on. At the present day erosion has almost ceased, and the fact that the cultivated terraces bordering the river, as well as the plain of Lower Egypt, are gradually rising with regard to the sea-level by reason of deposition of sediment shows that the bed of the river is also rising.<sup>2</sup> There is, therefore, no scouring action going on.

The fall of the river from Assuân to Cairo is a little over 6 inches per mile, a fall just sufficient to keep the fertilizing sediment in suspension when the river is not at its lowest. The magnificent Nile Valley, of an average breadth of 10 miles, cut down through a table-land of an average elevation of 800 to 1000 feet, capped by Eocene limestone, and extending above Cairo for a distance of 300 miles, is a physical feature which must impress the observer with the conviction of the enormous length of time during which the Miocene erosion was in progress.<sup>3</sup>

The next point to which I wish to refer is the fact that in the Nile we have a conspicuous example of a river running across escarpments. Taking these in succession from the north up stream, they are:—1, the escarpment of the Eocene limestone; 2, that of the Cretaceous limestone; 3, that of the Nubian Sandstone; and 4, in a less degree, that of the granitic and schistose rocks of Assuân. The dip of the strata towards the north, although generally almost imperceptible, and sometimes reversed, is greater than the slope of the river-channel. In consequence of this the transverse course of the river was a physical necessity, if it was to enter the Mediterranean; but owing to the low angle of dip of the beds, and their wide range, the fact is not so evident as it would be if the dip were greater, and the range more contracted. Zittel has suggested that the river once entered the Red Sea. This I cannot conceive to have been possible at any point above Cairo, except during early Pliocene times when Lower Egypt was submerged to a depth of about 220 feet, and the waters of the Red Sea, united to those of the Mediterranean, overflowed the entire region below this level. In this sense the statement is true, but not otherwise. As in the case of the streams traversing the Chalk and Greensand escarpments in

<sup>1</sup> It is now becoming generally recognized that Miocene strata are absent from the Egyptian area, which bears out the view above stated. See 'The Geology of Egypt,' by Philip Lake, 'Science Progress,' vol. iv. (1896) p. 395; also Prof. Mayer-Eymar, 'Zur Geologie Aegyptens,' Vierteljahrsschr. Naturf. Gesellsch. Zürich, 1886.

<sup>2</sup> Otherwise the river would have ceased to reach the cultivated plain on its banks.

<sup>3</sup> From Zittel's section across the Nile Valley it will be seen that the plateau on the eastern side of the valley rises over 1500 feet in some places, and I am inclined to think that the average height may be 1000 feet.

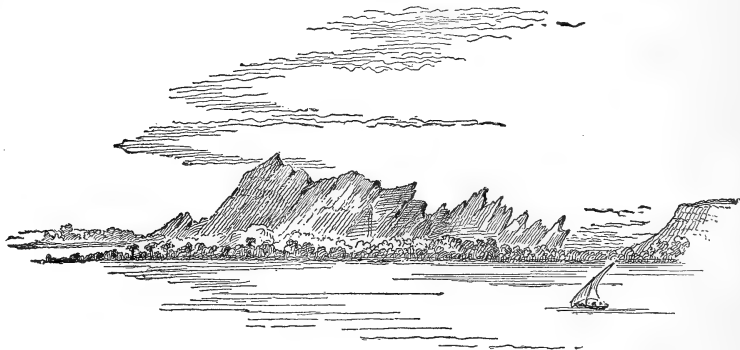
the Wealden area, once the course of the river had been selected as the land emerged from the ocean in Miocene times, that course was never abandoned. The physical features of the region between the Nile and the Red Sea are quite inconsistent with such an hypothesis as that referred to.

### 3. Faults.

Besides a depression along the general course of the Nile Valley in the surface of the Eocene and Cretaceous beds, which must have guided the original course of the river northward, faults appear to have played an important part. They have been noticed by Dawson,<sup>1</sup> E. H. Johnson and H. D. Richmond,<sup>2</sup> Lyons,<sup>3</sup> and others. That which follows the line of the valley above Cairo has long been known.

Another remarkable fault is shown on the right bank about 5 miles below Farshût, following the course of the stream, with the downthrow on the western side, along which the beds are highly tilted and bent. A third case at Gebel Ain, above Luxor, is remarkable for the high angle at which the beds are seen to dip (fig. 1). This is visible in the left bank of the river, and appears to follow its course in that locality.

Fig. 1.—*Sketch at Gebel Ain, showing beds of limestone highly tilted along line of fault.*



[The escarpment of Eocene limestone is in the background to the right.]

I refer to these cases merely in order to show that the line of erosion of the primæval Nile was sometimes directed by the dislocations of the strata; but some of the faults are transverse to those which run parallel to the course of the stream, such as that at Maghâghah.<sup>4</sup>

<sup>1</sup> 'Modern Science in Bible Lands,' Appendix, 1888.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 482.

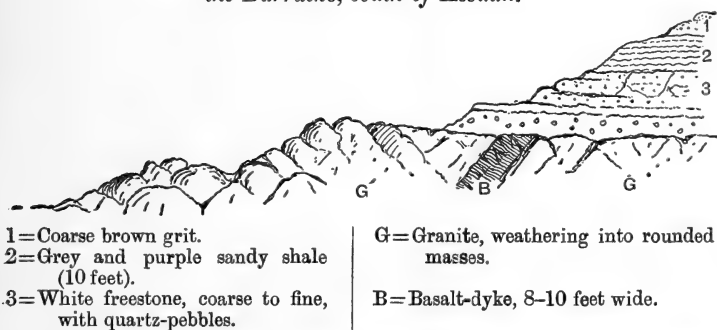
<sup>3</sup> *Ibid.* vol. l. (1894) p. 541.

<sup>4</sup> Described by Johnson and Richmond.

#### 4. Relation of the Nubian Sandstone to the Granite and Schist of Assuân.

The only other point bearing on the geology of the Nile Valley to which I shall refer is the relation of the Nubian Sandstone to the older rocks of Assuân and the First Cataract. I should not have thought it necessary to do so, had not some observers supposed that the granite is intrusive into the newer formation. From an examination of the junction at several places, I have satisfied myself that there is no good warranty for this view. Undoubtedly the original surface of the older rocks was very uneven, consisting of ridges and furrows against, and upon, which the Sandstone Series was deposited. But the latter is not in the least 'baked' or 'altered' along the surface of contact, while the local basement-beds are often conglomeratic, pebbles of quartz, probably derived from the granite itself, being abundant. The junction is remarkably well shown above the ancient quarries, along the pathway leading to the barracks which overlook the Nile Valley, and the accompanying sketch was taken on the spot.

Fig. 2.—*Sketch of junction of granite and Nubian Sandstone near the Barracks, south of Assuân.*



The general structure of the locality is illustrated in the above section, taken from the banks of the river opposite the Island of Sehél, about 3 miles south of Assuân.

#### 5. Age of the Nubian Sandstone.

I shall not enter here on the question whether the whole of the Nubian Sandstone of the Nile Valley is of Cretaceous age, or whether it is partly Carboniferous. It is a problem which can be solved only by a careful survey of the whole region, which, as announced, is to be immediately undertaken by the Egyptian Government, under the direction of Capt. Lyons. I will only observe that some portions of the formation which I was able to examine in the Nile Valley are very unlike in mineral composition

to the Nubian Sandstone of Cretaceous age in Arabia Petræa and the Arabah Valley. This, however, is not surprising, considering the distance by which the two localities are separated, and does not afford any evidence that the formations are of different geological ages. In Arabia Petræa and along the eastern side of the Wadi-el-Arabah, the Nubian Sandstone is distinguished by rich red and purple or yellow colouring; the base is a conglomerate where it rests upon the crystalline rocks, and bands of clay or marl are rare.<sup>1</sup> On the other hand, as Lyons has shown, bands of clay are common in the Nubian Sandstone of Upper Egypt,<sup>2</sup> while the prevailing tint is light grey or brown, sometimes slightly tinged with red or pink. It is this stone which was so largely used in the building of the temples, and which has wonderfully resisted the effects of time.

## PART II.

### 6. The Levels of the Ancient Nile.

The evidence upon which the former greater volume of the Nile waters is inferred may be considered under two heads: (1) the river-terraces now beyond the reach of the highest floods, and (2) the old river-channels through which the waters cannot now pass, owing to difference of level. We shall consider these separately.

(1) *The River-terraces*.—In order to arrive at a clear knowledge of the bearing of this subject upon the question of the former volume of the Nile, it may be observed that the general structure of the valley as far as the First Cataract is, on the whole, remarkably uniform and simple. First, we have the valley itself shut in on either hand by the escarpments along which the plateaux of the Libyan and Eastern<sup>3</sup> deserts terminate; then, from the base of these escarpments there extends, on one or both sides, a slightly sloping terrace, formed of alluvial gravel, sand, or mud, of varying breadth, and terminating along a well-defined bank rising above a lower terrace which, in turn, breaks off along the banks of the river. This lower terrace (No. 1) consists of Nile mud, is richly cultivated or planted with palms or other trees, and is watered by the Nile inundations. The terrace above (No. 2) is absolutely destitute of vegetation, and its surface, formed of yellowish gravel or sand, contrasts in a striking manner with that of the lower terrace above which it rises. Other terraces at higher levels there may be in Middle Egypt, connected with the epoch of Pliocene submergence,<sup>4</sup> of which I shall have to speak presently; but the above

<sup>1</sup> 'Geology of Arabia Petræa,' Mem. Palest. Explor. Fund (1886), p. 54.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. I. (1894) p. 533.

<sup>3</sup> Generally called in the maps 'the Arabian Desert,' because largely inhabited by Arabs, but the name is misleading.

<sup>4</sup> Or during the emergence of the Miocene period, and represented by the caves and terraces at levels of about 500 feet described by Sir J. W. Dawson, 'Modern Science in Bible Lands,' Appendix, 1888, p. 541; and Geol. Mag. 1884, pp. 289-92.

description applies, with slight modification, to the whole valley as far as Assuân, and also between this and the Second Cataract, as may be gathered from the descriptions of Prof. Leith Adams and Capt. Lyons. The following section, taken across the valley at Farshût, is intended to show its general structure :—

Fig. 3.—Section at Farshût.



Terrace 1.—Liable to floods. Cultivated.

Terrace 2.—Older. Beyond the reach of floods.

Terrace 3.—Plateau of Eocene limestone at the border of the Desert.

That terrace No. 2 was originally the bed of the Nile there cannot be a doubt, and the occurrence of fluviatile shells in the strata is not required to strengthen this view. These were found by Leith Adams both above and below the First Cataract. Where I examined the beds, at Thebes and Assuân, I was not so fortunate as to find them. I will now mention a few localities where terrace No. 2 may be observed above Girgeh.

(a) *Girgeh*.—Where the valley widens a short distance above Girgeh, terrace No. 2 is distinctly seen, rising, say, about 80 to 100 feet above the cultivated terrace (No. 1). The level is rather higher than that farther up the valley. This may be accounted for by the Pliocene submergence, which would have affected the level of the river nearly as far as Girgeh; to this I shall again have to refer.<sup>1</sup>

(b) Above Kasr-es-Sayad the western escarpment of the Eocene limestone recedes for a great distance from the river-side, and here

<sup>1</sup> Dawson believes that the sea-waters reached as far as the First Cataract, supposing the 500-foot caves and terrace above the Nile at Gebel Mokattam to be due to submergence, which is uncertain in the absence of marine forms at this level. But the only certain raised sea-beach—that discovered by Prof. Fraas—is nearly 300 feet lower, and the sea-waters in this would not have reached farther than Girgeh, as above stated.

[For this determination I am indebted to Mr. Garstin, Chief of the Egyptian Public Works Department, who kindly sent me the following statement while this paper was passing through the press :—

‘Distance from Cairo in kilometres at which the high-water level was 220 feet over the sea :

1890=562 kilometres from Cairo.		
1891=563	”	”
1892=558	”	”
1893=566	”	”
1894=560	”	”
1895=564	”	”

‘The mean is 563 kilometres from Cairo,’ or 339·57 miles. This distance would reach to within 2 miles of Girgeh, which is 341½ miles from Cairo.—April 25th, 1896.]

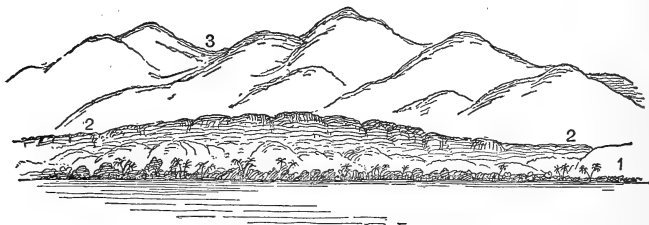
both the cultivated plain and terrace No. 2 extend over very large areas. The latter is very distinct, rising in a bare yellowish slope of 40 to 50 feet (estimated) above terrace No. 1, and stretching to the flanks of the valley.

(c) On the right bank of the Nile at El Kab, about 15 miles south of Esneh, both terraces are clearly defined. Here a village of mud-huts is built upon terrace No. 2, below which is the cultivated flat, and behind rises a fine cliff of Cretaceous limestone.

(d) The sloping plain on which was built the city of Thebes is referable to the second terrace. It consists of beds of sand and gravel, laid open near the temple of Medinet Abu, bounded inwards by the grand semicircular escarpment of the Eocene beds, and towards the river by the wide plain, richly cultivated and abundantly watered at Nile flood. From this plain rise in solitary grandeur the Colossi of Memnon,<sup>1</sup> and as it is improbable that they were originally (over 3300 years ago) erected on a basis liable to the floods of the Nile, we have here evidence that the bed of the river and the plains on its banks have been raised by repeated depositions of sediment;—an inference borne out by other examples of a similar kind. Terrace No. 2 forms a wide plain west of Thebes, but it becomes very narrow at Kurnah in the opposite direction. From this neighbourhood, at El Waddi, Gen. Pitt-Rivers obtained some flint-flakes supposed to be of human workmanship, embedded in banks of undisturbed gravel.<sup>2</sup>

(e) Opposite Kôm Ombo, on the western bank of the river, the floor of the old Nile is laid open on the banks of the river itself, and is peculiarly interesting, as it is composed of laminated brownish mud lying at the foot of a range of sandhills, and rising from 30 to 50 feet above the margin of high Nile. I give here a sketch of this interesting section, which was pointed out to me by Capt. Lyons.

Fig. 4.—*Terrace of Old Nile mud near Kôm Ombo.*



1=Low terrace of clay, covered with vegetation.

2=Old terrace of Nile mud, laminated: 30 to 40 feet above the highest floods.

3=Bank of sandhills.

Nile in foreground.

<sup>1</sup> 1500 B.C. according to Dr. Budge, 'The Nile,' 3rd ed. p. 13; 1400 B.C. according to Prof. Rawlinson, 'Ancient History,' p. 39.

<sup>2</sup> Journ. Anthropol. Inst., May 1882; quoted by Prestwich, 'Geology,' vol. ii. p. 483. Dawson, however, doubts that these were the work of man ('Modern Science in Bible Lands,' Appendix, 1888, p. 541).



In some places, between Silsileh and Assuân, the second terrace seems to merge at the surface into the low terraces of the Nubian Sandstone, the grand escarpment of the Eocene limestone having given place to the Nubian Sandstone. In this district Leith Adams discovered numerous river-shells at a level of at least 120 feet above the highest Nile of the present day.<sup>1</sup>

(f) *Old terraces above the First Cataract.*—According to Leith Adams, the old terraces now rising far above the highest floods of the Nile at the present day may be traced at intervals along the valley between the First and Second Cataracts. One of the most remarkable instances occurs at Derr, the capital of Nubia, about 80 miles below the Second Cataract. Here, above the cultivated terrace liable to floods, rises a cliff of sandstone, above which is a second sloping terrace, rising from 110 to 130 feet above highest Nile, formed of pebbles, among which Adams found numerous specimens of *Cyrena fluminalis*, a shell now abundant in the Nile waters. Some miles farther northward, in the same terrace, the same shell was found in reddish sandy soil, together with *Bulimus pullus*. Similar terraces were recognized at Gharbea, north of Korosko, at Dakke and Gertasse, rising from 60 to about 100 feet above the highest Nile floods, and containing several species of freshwater mollusca.<sup>2</sup> These observations are confirmed by Capt. Lyons, who speaks of the large sheets of gravel, which in Nubia extend for a length of 7 or 8 miles along the Nile bank at Debera, 8 miles north of Wadi Halfa, at 100 feet above the present Nile floods, and containing shells, such as *Ætheria semilunata*, *Cyrena fluminalis*, *Unio*, and *Paludina*.<sup>3</sup>

(g) But these evidences of former higher levels do not cease at the Second Cataract, for Capt. Lyons has shown,<sup>4</sup> by the position and inscriptions on the rocks and temples dating as far back as 2200 B.C., that the river then rose to a maximum of 27 feet above its present flood-level; the amount of rise decreasing as time went on. Lyons suggests that these variations of the river were caused by earth-movements; but it seems more probable that they are referable to the same general causes as those which have given rise to the high terraces occurring at intervals down the valley into Lower Egypt.

Thus we have seen that, throughout a distance of between 600 and 700 miles above Cairo, the evidence derived from the terraces is cumulative, and tends to prove that the original surface of the Nile waters stood at a level varying from 50 to 100 feet or more above that of the present day.

### PART III.

#### 7. Old River-Channels.

How many channels of the primæval Nile there may be which the river has deserted in consequence of the fall of its surface I

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xx. (1864) p. 9.

<sup>3</sup> *Ibid.* vol. I. (1894) p. 543.

<sup>2</sup> *Ibid.* pp. 13, 14.

<sup>4</sup> *Ibid.* p. 544.

am unable to state, but we are happily in possession of exact information regarding two of them: one at Kôm Ombo, about 26 miles below Assuân, and one at this latter place itself. Of these I now proceed to give some detail.

(1) Kôm Ombo (or Kôm Ombos).—The remarkable ruins of two temples perched on a cliff overhanging the river, which is constantly being undermined, and is threatened with eventual destruction, derive much interest from the fact that they are built on the alluvia of the old Nile, and formed part of its ancient bed before the waters had fallen away to their present level. The surface of the highest Nile-floods does not reach to within more than 12 metres (39·38 feet) of this old terrace, as stated by Mr. W. Willcocks, of the Egyptian Public Works Department,<sup>1</sup> and both he and Leith Adams discovered shells of the genera *Cyrena* (*Corbicula*), *Unio*, and *Paludina* in the alluvial beds at a level of 11 metres (36·08 feet) above present highest floods. In order to compare the relative levels of the floods of the present day with those of the ancient river at this place, we ought to add about 30 feet to that of the floor, which will show a difference of about 70 feet for the respective surfaces.

(2) Assuân, which is built on the cultivated terrace at the northern or lower end of the First Cataract, is connected with Shellâl at the southern or upper end, not only by the river, but by two valleys, one or both of which were probably river-channels when the river flowed at a higher level. They lie parallel to each other and to the Nile itself on its eastern side.<sup>2</sup> Of one of these only can I speak with certainty, time not having allowed me to make a proper examination of the other. Along this, the more easterly of the two valleys, the railway connecting Assuân and Shellâl is carried for a distance of about 7 miles. It is about half-a-mile wide, running between rugged slopes of granite capped by horizontal courses of Nubian Sandstone. The floor of the valley is even, affording camping-ground for a tribe of Bedawîn Arabs, and is composed of sand, gravel, and mud rudely stratified.<sup>3</sup> The surface rises to a low saddle about 2 miles south of Shellâl, the height of which has been kindly determined for me by Capt. Lyons by levelling to be 83·41 feet (28·48 metres) above highest floods at Shellâl and the island of Philæ, which is opposite this village; and here, again, if we wish to compare the original height of the water-surface with that of the present day, we may add, as a safe estimate, 25 or 30 feet—making 108·41 feet as the amount of difference of surface during high floods. This level exceeds that at Kôm Ombo, but may be accounted for by the difference in the physical conditions of each place; the Nile being here narrowed and encumbered

<sup>1</sup> Report to the Government of Egypt on 'Perennial Irrigation, etc.,' 1894. Appendix vii. p. 13. Willcocks has also noticed *Ætheria nilotica* in the old Nile deposits both above and below Gebel Silsileh, *ibid.* p. 14.

<sup>2</sup> Baedeker's 'Guide to Upper Egypt' contains an excellent little map of the environs of Assuân (ed. 1892, p. 274).

<sup>3</sup> My first visit to this valley was in company with Capt. Lyons, who indicated its origin as an old Nile valley, a view which a subsequent visit fully confirmed.

by granite ridges, instead of having merely to find its way through a wide plain as at the latter place. Near the northern end of the railway-cutting above Assuân we find a deposit of the old Nile mud with bands of pebbles resting on the upturned edges of the ancient schists.

Fig. 5.—Section from the river-bank opposite the Island of Sehêl at the First Cataract.<sup>1</sup>



S = Nubian Sandstone and Conglomerate.

G = Granite forming the sides of the present and ancient channels of the Nile.

[Distance = over 2 miles.]

The valley now described was recognized by Leith Adams as an ancient river-channel, and in the alluvial deposits in the ravines north of it he was fortunate in discovering numerous shells, such as *Ætheria semilunata*, *Iridina nilotica*, and *Bulimus pullus*.<sup>2</sup> Time did not permit of a careful search on my own part.

From the foregoing facts and considerations it will be observed that the evidence of a former higher Nile surface afforded by the old terraces is confirmed by that of the old channels. The waters which formerly extended over the floor of the Nile Valley with a breadth of several miles are now confined by banks which are seldom  $\frac{1}{2}$  mile apart, and this has resulted, not in consequence of the deepening of the channel, but by reason of the diminution in volume of the waters themselves. This is shown by the fact that there is no scouring of the Nile channel, the current being insufficient for this purpose; and besides this, the borings which have been made show that the bed of the river is composed of alluvial mud of considerable depth.<sup>3</sup> The bed is, in fact, rising by accessions of deposit comparable with that which is annually spread over the cultivated lands on either side during the high floods, and which has been estimated by Mr. Willcocks, Engineer to the Public Works Department, to amount to 0·12 metre (4·7 inches) in 100 years.<sup>4</sup> We are therefore obliged to have recourse to another explanation—namely, the decrease, and in part cessation, of the rainfall over the entire hydrographical basin of the river—in order to account for the decrease in volume.

The hypothesis of a former greater volume of the river has the support of Leith Adams, Zittel, Lyons, and others, and may therefore be considered as an accepted hypothesis: though it is not, as it seems to me, brought forward with sufficient prominence by writers

<sup>1</sup> It is near this place that the great Nile embankment is to be made.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xx. (1864) p. 15. The species were determined by the late S. P. Woodward, of the Natural History Museum.

<sup>3</sup> At Silsileh, where the Nubian Sandstone crosses the river, the solid rock was still not met with after boring to a depth of 20 to 25 metres (65 to 73 feet) below low Nile, 'Rep. Technical Commission,' p. 21 (1894).

<sup>4</sup> Report on 'Perennial Irrigation of Egypt,' 1894, p. 12.

on Egyptian geography, who have had generally other objects of investigation before their minds, but I should like to quote in this connexion the language of Prof. Zittel as follows:—

‘Alle diese Thatsachen beweisen, dass der Nil einst ein weit mächtigerer und reissenderer Strom als heutzutage war, und dass die Gattung *Ætheria*, welche jetzt erst südlich von Assuan beginnt, früher weiter nach Norden verbreitet war.’<sup>1</sup>

## PART IV.

### 8. The Pluvial Period.

When traversing, in 1883–84, the fine valleys of the Sinaitic Peninsula and Arabia Petræa, the bottoms of which, now dry, are composed of alluvial deposits, I came to the conclusion that at a former period, and under different climatic conditions, they constituted the channels of an extensive river-system draining into the Red Sea.<sup>2</sup> It is only at rare intervals that rain falls over this region, in the form of spasmodic thunderstorms of short duration, and they are quite insufficient to account for the formation of valleys, sometimes a mile or more in breadth and hundreds of feet in depth. The dry river-valleys which open into the Nile, chiefly along the eastern side, tell a similar tale.<sup>3</sup> The streams which flowed along them, and by which they were excavated, have dried up and disappeared. The period during which this process of valley-erosion, of terrace-formation, and of high floods went on may well be designated ‘Pluvial’—extending from the Pliocene down through the post-Pliocene, and terminating with recent times. It is a term indicative of meteorological rather than geological conditions, though not unconnected with these.

## CONCLUSION.

The conclusion to which we are driven from a consideration of the above phenomena is that the Nile has decreased in volume to a large extent, as compared with that of primæval times. It only remains to consider how and when this decrease has arisen.

(1) As regards the manner in which this change took place, there can be only one answer: by the drying up of its sources and tributaries owing to decrease in the rainfall. Throughout 1200 miles of its course, the river runs through a region well-nigh rainless, where its waters are subject to a constant drain through evaporation; in consequence of which its volume at Khartum is considerably larger than it is at Cairo; and the only wonder is, when one contemplates the extent of this evaporation, especially during the

<sup>1</sup> ‘Palæontographica,’ vol. xxx. (1883) p. 137. Zittel founds this opinion mainly on the discoveries by Leith Adams of fluviatile shells in the terraces beyond the reach of the highest floods.

<sup>2</sup> ‘Geology of Arabia Petræa, etc.’ Mem. Palest. Expl. Fund, *passim*.

<sup>3</sup> Such as the Wadi Sonnur, opposite Beni Suef; W. Tarfeh, north of Minieh; W. Siut, opposite the town of the same name; W. Gassab, opposite Girgeh; W. Keneh, a valley with numerous branches, opposite Keneh; and W. Abu Wassel, below Luxor.

hotter months, that its waters ever reach the Mediterranean at all. That they do so is owing to the fact that it is during these months that the waters rise by reason of the Abyssinian floods. The numerous dry valleys which enter the Nile Valley in Middle and Upper Egypt and Nubia show that this region was once abundantly watered.

When we consider the enormous area of the hydrographical basin of the Nile, estimated at 1,100,000 square miles, we can understand how a slight climatic change in the direction of increased humidity and decreased temperature would cause an enormous expansion of volume of Egypt's great river. This is really what I believe took place; and it now remains to consider the period to which we should refer these altered conditions.

(2) During the Miocene period, when the primæval river was channelling out its bed, and when the land was relatively higher than at present as regards the surface of the Mediterranean, the climatic conditions may have been altogether different from those of the present day over the Nile Basin; but whether this was the case or not, we have good grounds for believing that during the subsequent Pliocene period, when Lower Egypt was submerged to a depth of over 200 feet, and the sea stretched up the Nile Valley for several hundred miles, the conditions were different from those of the present time. The increase of water-surface must have been accompanied by increased humidity, and a lowering of temperature, compared with that of Miocene times. And when these Pliocene conditions gave place to those of the Pleistocene period the climatic conditions in the same direction must have been still further advanced.<sup>1</sup> The lowering of temperature over all the European regions to the north must have greatly affected those we are now discussing. To what extent the annual mean temperature of the subtropical regions of Africa was lowered during the Glacial period of the temperate zone can scarcely be estimated with precision, but that the general effect was brought about cannot, as it seems to me, be contested. My own view is that in these regions the climatic conditions were similar to those of Europe at the present day, both as regards temperature and rainfall; and if such were even approximately the case, it is easy to account for the vastly greater volume of the Nile waters as compared with those which render Egypt not only a habitable but a fertile country. For this epoch I adopt the term first, I believe, suggested by Mr. Jameson for this part of the world—namely, the Pluvial period.<sup>2</sup>

<sup>1</sup> Lyons considers that at this period (post-Pliocene) there was 'a considerable rainfall' over the area of the Libyan Desert, though not excessive. *Quart. Journ. Geol. Soc.* vol. 1. (1894) p. 542. See also E. A. Floyer, *ibid.* vol. xlviii. (1892) p. 580.

<sup>2</sup> Capt. Lyons has unintentionally misrepresented my meaning when he suggests that I have restricted the term 'Pluvial period' to that represented by the Glacial of Europe. On the contrary, I expressly regard it as extending from the Pliocene down to the close of the post-Pliocene, as will be seen on referring to my memoir on the 'Physical Geology of Arabia Petræa and Palestine,' *Mem. Palest. Explor. Fund* (1886), pp. 69, 113.

18. *On CERTAIN GRANOPHYRES, MODIFIED by the INCORPORATION of GABBRO-FRAGMENTS, in STRATH (SKYE).* By ALFRED HARKER, Esq., M.A., F.G.S., Fellow of St. John's College, Cambridge. (Communicated by permission of the Director-General of the Geological Survey. Read February 26th, 1896.)

[PLATES XIII. & XIV.]

THE district of Strath in Skye, which has so often formed the subject of geological description, has been assigned to me to be mapped in detail for the Geological Survey; and while engaged in this duty, during the past summer and a portion of the autumn, I had occasion to study the complex series of eruptive rocks which extends from Loch Slapin on the west to the Sound of Scalpay and Broadford Bay on the east. Among the features of interest connected with these igneous rocks, special importance attaches to their relations one to another, and this subject has received due attention. The full details will be fitly deferred until the appearance of the official Memoirs; but, with the sanction of the Director-General, I now present to the Society the following brief account of certain minor intrusions of granophyre illustrating a peculiarity which, I believe, has not yet received notice.

The granophyres of Skye have been described, as a whole, by Macculloch, Oeynhausén and von Dechen, J. D. Forbes, Sir Archibald Geikie,<sup>1</sup> Prof. Zirkel, and Prof. Judd. Despite mineralogical and textural variations, these rocks have a general community of characters, which they share also with rocks of various ages in other regions. The examples to be described, however, present quite exceptional features, which seem to be worthy of examination. They form five distinct intrusions lying north and west of Loch Kilchrist and 2 or 3 miles south-west of Broadford (see Map). At this locality occurs a large tract of massive volcanic agglomerate, which has its own interest as marking, according to Sir A. Geikie,<sup>2</sup> the site of a large volcanic vent. It is within, and on the borders of, this agglomerate-tract that the intrusions are situated. In the surrounding district numerous other masses of granophyre occur. Immediately to the north is the large boss forming the Red Hills; to the south is another rising into Beinn-an-Dubhaich, while several smaller intrusions are perhaps to be regarded as offshoots from these large ones; but from all of these the peculiar rocks in question are at once picked out in the field as presenting marked differences from them.

<sup>1</sup> I follow Sir A. Geikie in grouping all the Tertiary acid rocks of this region under the collective name 'granophyre,' which is strictly applicable to most of them, although there are transitions both to the granitoid type on the one hand and to fine-textured 'quartz-felsites' on the other.

<sup>2</sup> Trans. Roy. Soc. Edinb. vol. xxxv. (1888) pp. 107-109.


## GEOLOGICAL SKETCH-MAP

Beimn

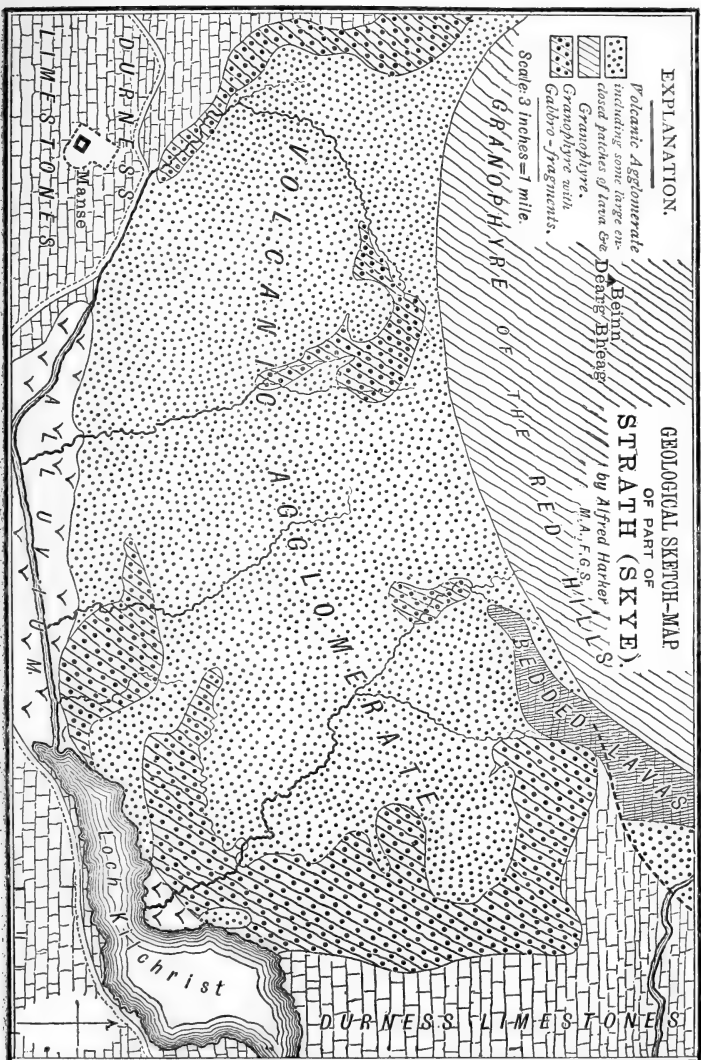
STRATH (SKYE)

Dear Bheag

Giraniophilyre.

 Granophyre with  
Gabbro-fragments.

Scale: 3 inches = 1 mile



Compared with what may be called the normal granophyres of the district, these rocks are darker and manifestly richer in the iron-bearing minerals. Examination shows, too, that they are decidedly denser: ten specimens gave specific gravities ranging from 2.56 to 2.73, with a mean of 2.66, while twenty specimens of the normal granophyres of the district gave from 2.51 to 2.66, with a mean of 2.58. Closer inspection often reveals a mottled appearance, due to the dark minerals tending to cluster in vaguely defined patches, and in places these patches become more distinct and are seen to represent enclosed fragments of some basic rock. In other respects, for example, in the prevalence of the micrographic structure, in the drusy character of the more coarsely textured type, etc., these rocks show a close correspondence with the normal granophyres of the district. It cannot, of course, be asserted that they agreed precisely with the latter as regards the composition of the original magma, but it will be shown that the differences which now exist are certainly due, at least in the main, to the taking up and partial dissolution by the acid magma of foreign rock-fragments of more basic composition.

It is to be observed that these peculiar granophyres do not occur as marginal modifications of, or as having any visible relation to, granophyres of the normal kind, but as independent intrusions. Moreover, the special characters of these rocks are distributed with considerable uniformity throughout each intrusion. Another point to be noticed is that the enclosed rock-fragments have not been derived from the rocks which border the intrusions as seen in outcrop. Excepting that the most easterly and the most westerly of the intrusions are in part bounded by limestone, the rock in contact is everywhere the volcanic agglomerate. The rock-fragments in the agglomerate are chiefly of sandstone and grit, probably Jurassic, and basalt similar to that of the bedded lavas of the district. The included fragments in the granophyre are in general of gabbro, which I have not detected in the agglomerate. They were therefore derived from some subterranean source, and, as we have seen, from such a depth as to allow of their becoming distributed with some regularity through the involving magma prior to the consolidation of the latter in its present surroundings.

The literature of foreign fragments enclosed in igneous rocks is voluminous, but it gives little information bearing on such a case as the present, where portions of a basic rock have been enveloped and attacked by an acid magma. Indeed, Zirkel<sup>1</sup> remarks that 'caustic' action is not known in the case of fragments enclosed in granites and syenites. The fullest account of such phenomena is that given by Prof. Sollas<sup>2</sup> in his description of the relations of the granite and gabbro of Barnavave in the district of Carlingford. This occurrence has obvious points in common with the one under discussion: some of the differences between the two will be brought out in the following pages. The modifications exhibited by the

<sup>1</sup> 'Lehrbuch der Petrographie,' 2nd ed. vol. i. (1893) p. 593.

<sup>2</sup> Trans. Roy. Irish Acad. vol. xxx. pt. xii. (1894) pp. 477-512.



Carrock Fell granophyre near its contact with a highly basic gabbro have been described by the present writer,<sup>1</sup> but there the dissolution of the derived material has been much more complete, and the analogy with the present case is more remote.

The xenoliths<sup>2</sup> in our granophyres are, as a rule, less than an inch in diameter, and have ill-defined outlines. Those readily recognized and identified by the eye as distinct foreign fragments are not common. In the thin slices undestroyed xenoliths are not frequent (6704), but altered xenocrysts are universally found.

Most of this derived material has undoubtedly come from a gabbro, and from one closely comparable with the ordinary gabbros of the district, such as that which occupies a considerable tract to the north-east of the Red Hills. Of these gabbros, as seen *in situ*, a summary description will suffice. They consist essentially of felspar and augite. The felspar is usually a labradorite, often in idiomorphic crystals showing some zony banding between crossed nicols. The augite is pale brown to almost colourless in thin slices. Instead of the true diallage-structure, parallel to the orthopinacoid, it has usually a delicate striation<sup>3</sup> parallel to the basal plane, often emphasized by a more or less pronounced schiller-structure. This frequently affects only part of a crystal, and it imparts a deeper brown tint to the slice. A rhombic pyroxene is rarely met with in the gabbros of this district, though it occurs in some of the coarser rocks of the Cuillin Hills, farther west. Recognizable olivine is not common, although it may sometimes be concealed by secondary magnetite-dust, as remarked by Prof. Judd. Original magnetite often occurs, in shapeless grains or patches. Needles of apatite are met with, but by no means constantly.

The gabbro-débris in the granophyre is seen in the thin slices in different stages of dissolution, but is for the most part completely disintegrated by the caustic or solvent action of the acid magma on some of its minerals. Those constituents which resisted such action have been set free, and now figure as xenocrysts, either intact or more or less perfectly transformed into other substances. At the same time the material absorbed has modified the composition of the magma, in the general sense of rendering it less acid, and this is of course expressed in the products of the final consolidation of the granophyre. In order to present in systematic form the observations made, it will be convenient to begin by enquiring what has befallen each of the chief constituents of the gabbro.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. li. (1895) pp. 125-139.

<sup>2</sup> [For convenience, I adopt Prof. Sollas's terms, 'xenolith' for an enclosed foreign rock-fragment, and 'xenocryst' for an isolated crystal of foreign derivation.]

<sup>3</sup> [I follow Mr. Teall (Quart. Journ. Geol. Soc. vol. xl. 1884, pp. 646, 647) in terming this structure simply a 'striation.' It does not appear to be a twin-lamellation, and I have not been able to satisfy myself as to its true nature. Mr. Teall regarded it, in the Whin Sill, as of secondary origin; but I have seen nothing leading to this conclusion in the gabbros of Skye, of Carrock Fell, of St. David's, etc., and its occurrence in 'xenocrysts' as detailed below would be difficult to reconcile with such a supposition.—March 12th, 1896.]

It is probable that the needles of apatite seen in most of the slices have been in part derived intact from destroyed gabbro-fragments, but this is not susceptible of decisive proof. Similar needles occur in the normal granophyres as well as in the gabbros of the district, and their rather capricious distribution in both rocks renders unsafe any argument founded on the relative amounts of the mineral in different slides.

It is the augite that affords the most conclusive proof of the extraneous origin of the xenocrysts, and this is due to the characteristic basal striation of the gabbro-augite, a feature not found in the augite of the normal granophyres. In the recognizable enclosed fragments of gabbro (6704)<sup>1</sup> the augite shows no change except a conversion to brownish-green, rather fibrous hornblende at the edge of the crystal, a transformation very common in the ordinary gabbros of the district (Pl. XIII. fig. 1). In the isolated xenocrysts the conversion to hornblende is usually far advanced, and in these rocks in general this mineral predominates over augite. It is yellowish to brownish-green or sometimes greenish-brown in colour, and of compact (as contrasted with fibrous) structure. Very often there is a core of unchanged augite with the basal striation that indicates its derivation from gabbro, and the traces of this structure are sometimes seen—even when the conversion to hornblende has been complete (Pl. XIII. fig. 3). Failing this evidence, the derivation of the hornblende can often be inferred from the irregular shape of its crystals, or from its enclosing abundant shapeless grains of magnetite. On the other hand, there is usually some hornblende presenting the crystal outlines proper to that mineral, and this must certainly have crystallized out from the modified granophyre-magma (Pl. XIII. figs. 4, 5). In some slides it is very plentiful. It does not differ materially in colour and pleochroism from the pseudomorphic hornblende. It may be remarked that when the latter encloses a core of unchanged augite the two minerals have the usual crystallographic relation, the *b* and *c* axes being common to both: in a clinopinacoidal section the extinction-angle of the augite is  $39^\circ$ , and of the hornblende  $18^\circ$ , on the same side of the vertical (2674). In addition to the augite plainly derived from gabbro, several of the slides contain rather rounded grains of augite showing neither basal striation nor partial conversion to hornblende. Unless these be relics of vanished xenoliths of basalt, they are probably to be regarded as having crystallized out directly from the modified granophyre-magma (Pl. XIII. fig. 1). This would not be remarkable, for augite is widely distributed in the normal granophyres of the district, where it often occurs side by side with original hornblende. Since, however, non-striated augite is found in many of the gabbros, the absence of this structure cannot in itself be regarded as conclusive.

At Barnavave the xenocrysts of diallage are described by Prof. Sollas as showing three different lines of alteration, the characteristic products being respectively granular augite, biotite, and green horn-

<sup>1</sup> The numbers between parentheses are those of the slides in the collections of the Geological Survey.

blende, with magnetite as a concomitant of each. Only the last of these three is clearly represented in the present case; newly-formed augite has been produced only indirectly by later secretion from the modified magma, and biotite has not been observed. At Carrock Fell the derived augite-crystals have been completely absorbed by the magma, and subsequent crystallization has given rise to new augite with hornblende and biotite.

Two of the slides (2674, 6703) afford evidence of the occurrence of xenocrysts of enstatite and hypersthene. There is a partial conversion to hornblende at the margin, while the interior is serpentinized or more rarely unaltered (Pl. XIV. fig. 7).

Occasionally pseudomorphs after olivine, apparently of 'pilitic' amphibole, are seen enclosed in the relics of striated augite (6704), or isolated in the granophyre-matrix (6703). There is no decisive criterion to determine whether these latter have come from the gabbro or from destroyed basalt.

Magnetite-grains of irregular shape are embedded in many of the augite-xenocrysts and the hornblende-pseudomorphs after them, and these do not differ from the grains in the original gabbro. Most of the abundant magnetite in the slices is, however, of a different kind, building perfect or imperfect octahedra. Though partly representing in substance iron ore absorbed from gabbro-débris, it is evidently a new crystallization from the modified granophyre-magma. At Carrock Fell the iron ore from the gabbro has been mostly, but not entirely absorbed; its partial survival may be due to its extraordinary amount and its highly titaniferous nature.

Distinct xenocrysts of gabbro-felspar are rare in the specimens sliced, but they are occasionally found, especially in the neighbourhood of actual gabbro-xenoliths. One suitably oriented crystal gave extinction-angles  $35^{\circ}$  and  $36^{\circ}$  in alternate lamellæ, and is presumably labradorite like the common felspar in the gabbros of the district. It has a marginal intergrowth of a more acid felspar, and, like the felspar-phenocrysts in all these granophyres, has served as nucleus for a growth of micropegmatite (6704). It is clear that most of the felspar of the enclosed gabbro-fragments has been completely absorbed by the enveloping magma. The result is seen in a great preponderance of soda-lime over potash-felspar in the rock as finally consolidated, compared with the normal granophyres of the district. This dominant felspar seems, however, to be chiefly the usual oligoclase, with quite low extinction-angles. At Barnavave xenocrysts of felspar (bytownite) seem to be common, though they are described as showing corrosion and other signs of change.

Apart from the peculiarities described, the rocks here dealt with present a general similarity to the normal granophyres. There are, however, one or two special points worth noting. Several writers, in describing the phenomena of xenoliths of acid rocks in basalts and diabases, have remarked a tendency to the formation of hollow spaces, usually filled by later products. Indications of the same tendency are not wanting in the present converse case, though

the circumstances are different. In one example are seen ring-like aggregates, about  $\frac{1}{10}$  inch in diameter, of hornblende-crystals, surrounding areas of clear quartz (6705, Pl. XIII. fig. 6). Quartz is frequently seen moulded upon hornblende-crystals, and, in several slides, penetrated by actinolitic needles (Pl. XIII. fig. 5). Such patches of quartz are quite different from the quasi-porphyrific grains common in the granophyres, and they seem to be of late formation—not necessarily secondary in the usual sense. They probably occupy what have once been vacant spaces formed in connexion with the destruction of xenoliths, and are quite distinct from druses. The latter are also found here just as in the normal granophyres, and are commonly filled by calcite and quartz (6707, Pl. XIV. fig. 8). In places it can be seen that the calcite-crystals project into the quartz, which again indicates that some of the latter mineral belongs to a very late stage in the history of the rock.

In addition to the relics of gabbro in these granophyres there are occasional traces of inclusions of other rocks. In particular there are granular aggregates consisting largely of hornblende and magnetite and presenting angular outlines to the surrounding matrix (6709, Pl. XIV. fig. 10). These probably represent xenoliths of basalt in an advanced stage of dissolution. At junctions of basalt and granophyre in other parts of Skye, as well as in Rum, Mull, and Ardnamurchan, detached fragments of basalt in the granophyre can be traced down to quite similar aggregates. In some cases the ferro-magnesian mineral produced is augite; in other cases, as here, it is hornblende. The greater part of the rocks now described contain no trace of foreign fragments other than those of gabbro.

There are, however, certain fine-textured portions of these granophyre-masses to which allusion has not yet been made, and the xenoliths in these are of a different character. The rocks occur on the margin of an intrusion or as a limb extending from the main body, and it is not easy to decide whether these and the more usual coarse type represent parts of a single intrusion. The granophyric structure is absent or scarcely developed in these fine-grained rocks, and one example shows strong fluxion (Pl. XIV. fig. 12). The enclosed fragments are very distinctly seen in hand-specimens, are subangular to rounded in shape, and are chiefly of dark compact lava, usually not more than  $\frac{1}{4}$  inch in diameter. One slide shows recognizable pieces of basalt, partly vesicular, of microlitic andesite, and of a quartzose grit (6701, Pl. XIV. fig. 11). Another shows only basalts, one with porphyritic feldspars (6702). Gabbro has not been identified, and the fragments noticed are all such as might be obtained from the agglomerate through which the intrusions have broken. They are in no case very highly altered, and, though their rounded form points to a certain amount of absorption by the magma, the latter has clearly not been very considerably enriched in basic constituents. In all these points these rocks contrast with the coarser granophyres described above.

The fine-textured rocks, with their evidence of comparatively rapid chilling, presumably represent the earliest irruptions of the acid magma. The marked difference between them and the coarser

granophyres seems to point to a distinct separation between them in respect of time and of the circumstances attending intrusion, and the contrast between the xenoliths of the two types decidedly enforces this reasoning. The portion of the acid magma first intruded appears to have merely enclosed fragments derived from the bounding walls, as many other igneous rocks have done in this and other districts. The main body of the granophyre-magma, which followed perhaps after some interval of time, has taken up foreign material amounting to fully  $\frac{1}{4}$  of its own bulk, derived, not from the bordering rocks, but from a gabbro probably at a considerable depth beneath. Herein, too, this latter case differs from the examples already cited from other districts. At Barnavave, where the evidence seems to be singularly complete, the phenomenon is essentially a 'contact' one. At Carrock Fell, owing to special circumstances upon which I have remarked elsewhere, the dissolution of the derived fragments has proceeded much farther than in the Irish example, but the broad relations are the same. The modification of the granophyre is confined to the neighbourhood of its contact with the gabbro, and disappears rapidly as we recede from that contact. In the instance now described in the Strath district, on the other hand, the abundant foreign material has been taken up prior to the intrusion of the magma into its present surroundings; has been distributed with some approach to uniformity prior to or during the intrusion; and, except for the relics described above, has then been absorbed into the granophyre-magma. The whole mass of each intrusion, excluding the fine-textured non-granophyric portions, has the same general characters throughout.

A question of general interest naturally arises from a consideration of this case. If the caustic action of the acid magma had been from any cause more energetic, and had sufficed to destroy the relics of gabbro as completely as has been effected at Carrock Fell, it would have been impossible (without careful and specially directed search) to detect any evidence of the incorporation of foreign material. Is, then, this factor an important one to be taken into account in discussing the origin of igneous rocks in general? Prof. Sollas, Dr. Johnston-Lavis,<sup>1</sup> and some other geologists would probably answer this question in the affirmative: I refrain from expressing any opinion.<sup>2</sup> The facts detailed above admit of obvious application to the problem; but it may be urged on the other hand that, were complete absorption of xenoliths to modify the composition of a rock-magma a frequent occurrence, cases of incomplete absorption such as that here described should be more common than they appear to be.

<sup>1</sup> Geol. Mag. 1894, pp. 47-48, 252-254; 'Natural Science,' vol. iv. (1894) pp. 134-140. Comp. A. von Lasaulx, Neues Jahrb. 1870, p. 713.

<sup>2</sup> Prof. Brögger has recently stated with much cogency the argument against the hypothesis of Kjerulf, Michel Lévy, and others, which supposes that granite-intrusions have in general 'assimilated' large portions of the neighbouring solid rocks. See 'Die Eruptivgesteine des Kristianiagebietes,' pt. ii. pp. 116, *et seqq.*, Videnskabselskabets Skrifter, I. Mathematisk-naturv. Klasse, 1895, No. 7.

## EXPLANATION OF PLATES XIII. &amp; XIV.

[The numbers in brackets are those of the figured slides in the collection of the Geological Survey at the Jermyn Street Museum.]

## PLATE XIII.

- Fig. 1. [6704.]  $\times 20$ . Granophyre showing native and foreign augites. To the right of the magnetite in the centre are several granules of augite proper to the granophyre: to the left of the figure is a gabbro-xenolith but little altered. In this the pale, well-cleaved augite forms ophitic plates enclosing the felspar, and the only alteration is a little marginal conversion into hornblende. The basal striation is not seen here. See p. 324.
- Fig. 2. [6705.]  $\times 40$ . Granophyre showing xenocrysts of augite derived from gabbro. This is proved by their retaining the basal striation and schillerization, which is combined with the ordinary orthopinacoidal twinning to give the 'herring-bone' structure. See p. 324.
- Fig. 3. [6709.]  $\times 20$ . Similar augite-xenocrysts converted into hornblende, but still retaining the basal schillerization. See p. 324.
- Fig. 4. [6705.]  $\times 150$ . Granophyre showing native hornblende. This is proved by its crystal-form. See p. 324.
- Fig. 5. [6708.]  $\times 150$ . Also showing idiomorphic hornblende, and, in addition, actinolitic needles embedded in clear quartz. See p. 326.
- Fig. 6. [6705.]  $\times 20$ . Ring of hornblende-crystals surrounding an area of clear quartz, to which they present idiomorphic outlines. See p. 326.

## PLATE XIV.

- Fig. 7. [2674.]  $\times 20$ ; polarized light, crossed nicols. Granophyre containing a xenocryst of enstatite, probably derived from gabbro. The interior of the crystal is converted into the usual serpentinous pseudomorph, but the margin is replaced by fibrous hornblende. Towards its right-hand end the crystal encloses two or three patches of compact hornblende, probably an original intergrowth. See p. 325.
- Fig. 8. [6707.]  $\times 20$ ; polarized light, crossed nicols. Granophyre with druse, occupied by quartz and calcite; a feature common to the ordinary coarse granophyres of the district. See p. 326.
- Fig. 9. [6707.]  $\times 20$ ; polarized light, crossed nicols. Granophyre showing delicate micrographic intergrowths of felspar and quartz. This also is characteristic of the ordinary granophyres of the district, from which the rocks described (when not showing actual relics of foreign material) differ only in their greater richness in the coloured minerals.
- Fig. 10. [6709.]  $\times 20$ ; polarized light, crossed nicols. An angular patch rich in hornblende and magnetite, probably an altered xenolith of basalt. See p. 326.
- Fig. 11. [6701.]  $\times 20$ ; outlines drawn by polarized light, crossed nicols. Fine-textured variety of granophyre (but non-granophyric), containing various xenoliths. In the lower part of the figure are fragments of altered glassy basalt; above and to the right is a piece of quartzose grit, and to the left of this a felspar-xenocryst. See p. 326.
- Fig. 12. [6702.]  $\times 10$ . Another fine-textured example, showing flow-structure. There are numerous xenoliths, chiefly of basalt, the smaller ones lenticular in form and arranged along the stream-lines. See p. 326.

## DISCUSSION.

Sir ARCHIBALD GEIKIE referred to the fact that Mr. Harker had been appointed to the Geological Survey only last spring, and that the present paper was the result of his first season's work. The region described by the Author was exceedingly familiar to the speaker, and he rejoiced to welcome this application of modern petrographical methods to its investigation. The paper had a double value. In the first place, it was important in regard to the local geology of the Western Isles, for it demonstrated by new evidence the posteriority of the granophyres to the gabbros; and in the second place, it had a suggestive bearing upon questions of theoretical interest regarding the possible modification of eruptive rocks by the incorporation of foreign material into their substance. He felt sure that further and even more extensive evidence of the same kind would be encountered in other parts of the same region of Skye. The inspection of Mr. Harker's specimens reminded the speaker of some puzzling rocks on the flanks of Glamich and other hills, which many years ago he saw to be too acid for the gabbros and too basic for the granophyres. He looked forward to having these and many other problems solved by the continuation of the same patient and skilled observation as had been shown in the investigations described in the present paper.

Lieut.-Gen. McMAHON said that he had listened to Mr. Harker with great interest, and looked forward with pleasure to studying the details of the paper. He was quite prepared to accept the Author's conclusions, because he had found augite in the granite of the Chor Mountain, North-western Himalayas, and attributed its presence to the digestion of fragments of basic rocks caught up by the granite. Mr. R. D. Oldham, Superintendent of the Geological Survey of India, had also found hornblende locally abundant in the granite of one part of the Chor, and attributed it to the granite having 'dissolved and absorbed the rocks whose position it occupies.' The presence of magnetite, however, stood on a different footing. It was rather abundant throughout the granite of the North-western Himalayas; but if the Author could show that its presence in the granophyre of Skye was due to the assimilation of gabbro, the fact would be very interesting.

Prof. MIERS called attention to a large mass of coarsely-granular basic rock which exists in the granophyre on the western flank of Marsco, and may be distinguished from the summit of Scur-na-Gillea as a dark band about 20 feet in breadth, traversing the face of the hill in a vertical direction.

Mr. W. W. WATTS pointed out that Prof. Sollas's researches at Barnavave had prepared the Society for this paper. He alluded to the association of gabbro and granophyre at so many places, including Radnor and Carrock Fell, and pointed out that the Whin Sill at Caldron Snout passed into a rock which was practically a gabbro embedded in granophyre.

Dr. DU RICHE PRELLER said that already on a former occasion

he had pointed out that Sir Archibald Geikie's conclusions with respect to the granophyre of the Western Islands of Scotland being intrusive into the gabbro, and therefore younger than the latter, were strikingly confirmed by the precisely similar phenomenon in the Island of Elba, where the Tertiary granite traversed the gabbro, diabase, and serpentine dykes. Mr. Harker had now shown the same phenomenon to exist also in Skye, and the speaker therefore wished to emphasize the analogy of Elba, the more so as Gen. McMahon had brought forward similar evidence with reference to the Himalayas.

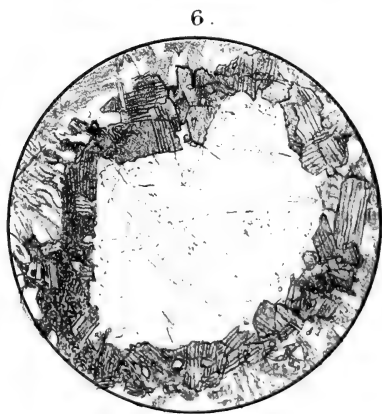
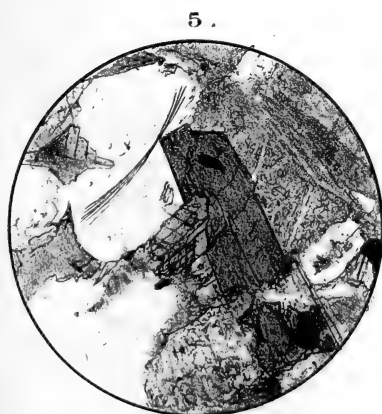
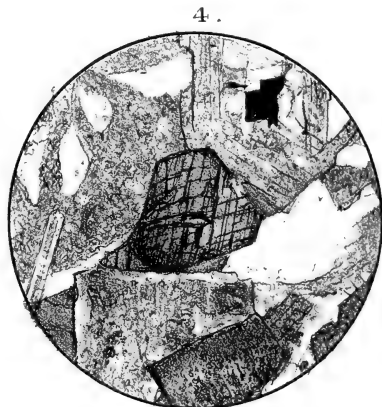
Mr. BARROW drew attention to the strong contrast between the evidence adduced by the Author to show actual absorption of part of these inclusions, and that published some time ago in his and Mr. Marr's work on the metamorphic aureole surrounding the Shap Granite. In the latter case, the Authors selected the amygdules in certain altered igneous rocks, and produced exceptionally clear evidence of the extremely limited migration of material that accompanied the development of new minerals in these bodies. Experience has shown that some of our best data are obtained in searching for the cause of such widely differing results. At present the evidence seems to suggest that the 'initial depth temperature' may be one of the chief factors in determining the amount of change produced.

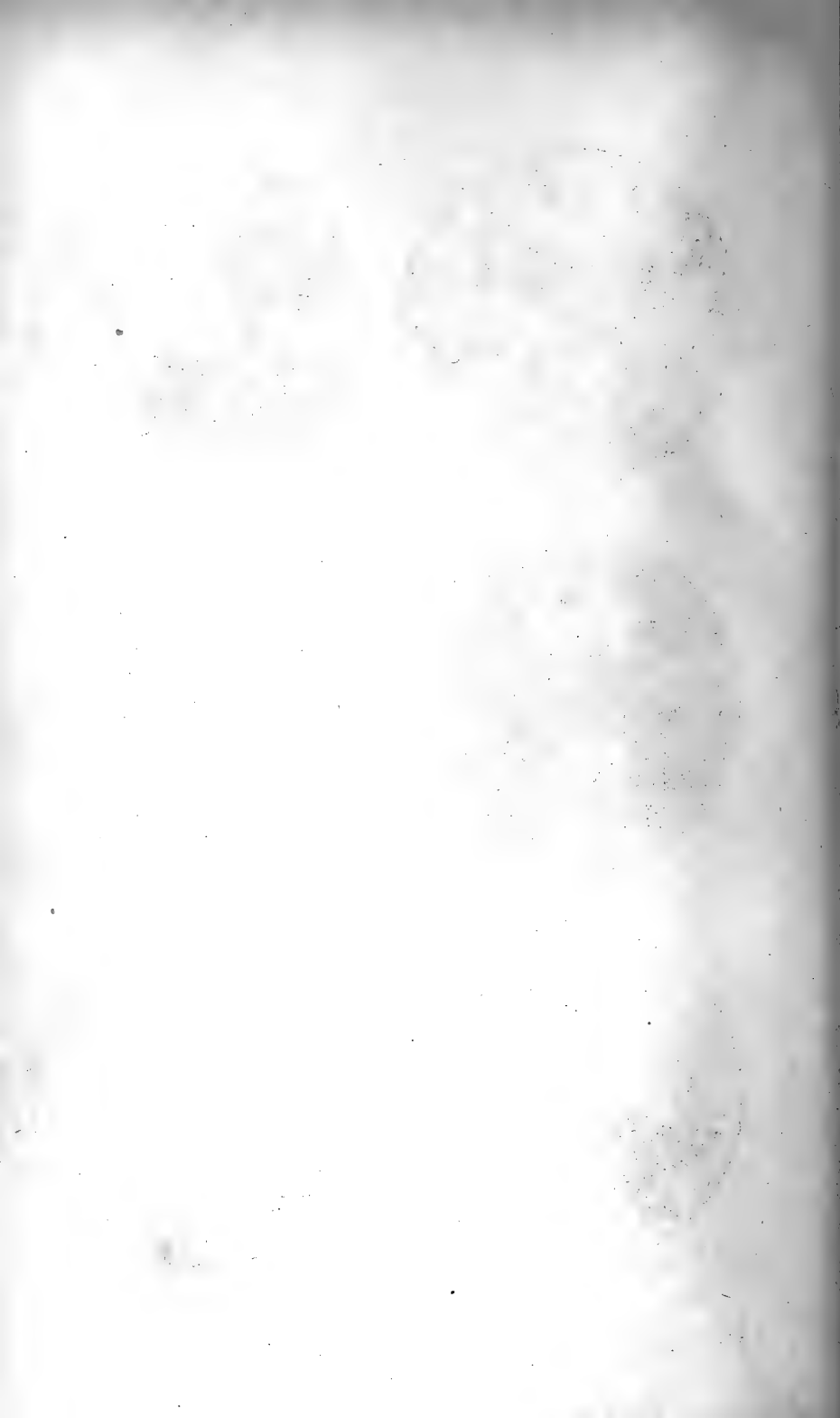
Mr. RUTLEY asked for further information regarding the geological structure of the area represented in the diagram. It was suggestive of proximity to a centre of eruption, and the irregular character of the patches mapped as gabbro-bearing granophyre, and their association with volcanic agglomerates and bedded lavas, favoured this belief. Cases such as this, of the absorption of fragments of a basic rock by an acid one, were, he thought, of comparatively rare occurrence. The reverse was more frequently the case. The exposures, described as dykes, might possibly be portions of buttress-dykes cutting irregularly through the agglomerates. The paper dealt with several points of great interest.

The PRESIDENT also spoke.

The AUTHOR briefly replied, thanking the speakers for their appreciation and criticism. Though the phenomena of incorporation of basic material by an acid magma appeared to be uncommon, at least on such a scale as in the examples described, the converse case of acid rocks absorbed into basic was illustrated by very many dykes in the Skye district. A considerable difference in acidity between the absorbed and the absorbing rock seemed to be as essential a factor in the process as that of temperature; hence the absorption of gabbros by granophyres observed in several districts. The peculiar intrusions described were possibly somewhat younger than the normal granophyres of Skye; but wherever these latter were seen in junction with gabbros in the area as yet mapped by the Author, the same relation, namely, the acid intrusion succeeding the basic, was invariably verified.







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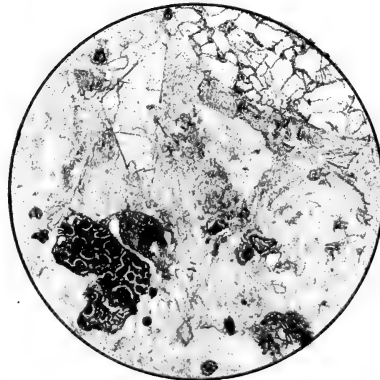
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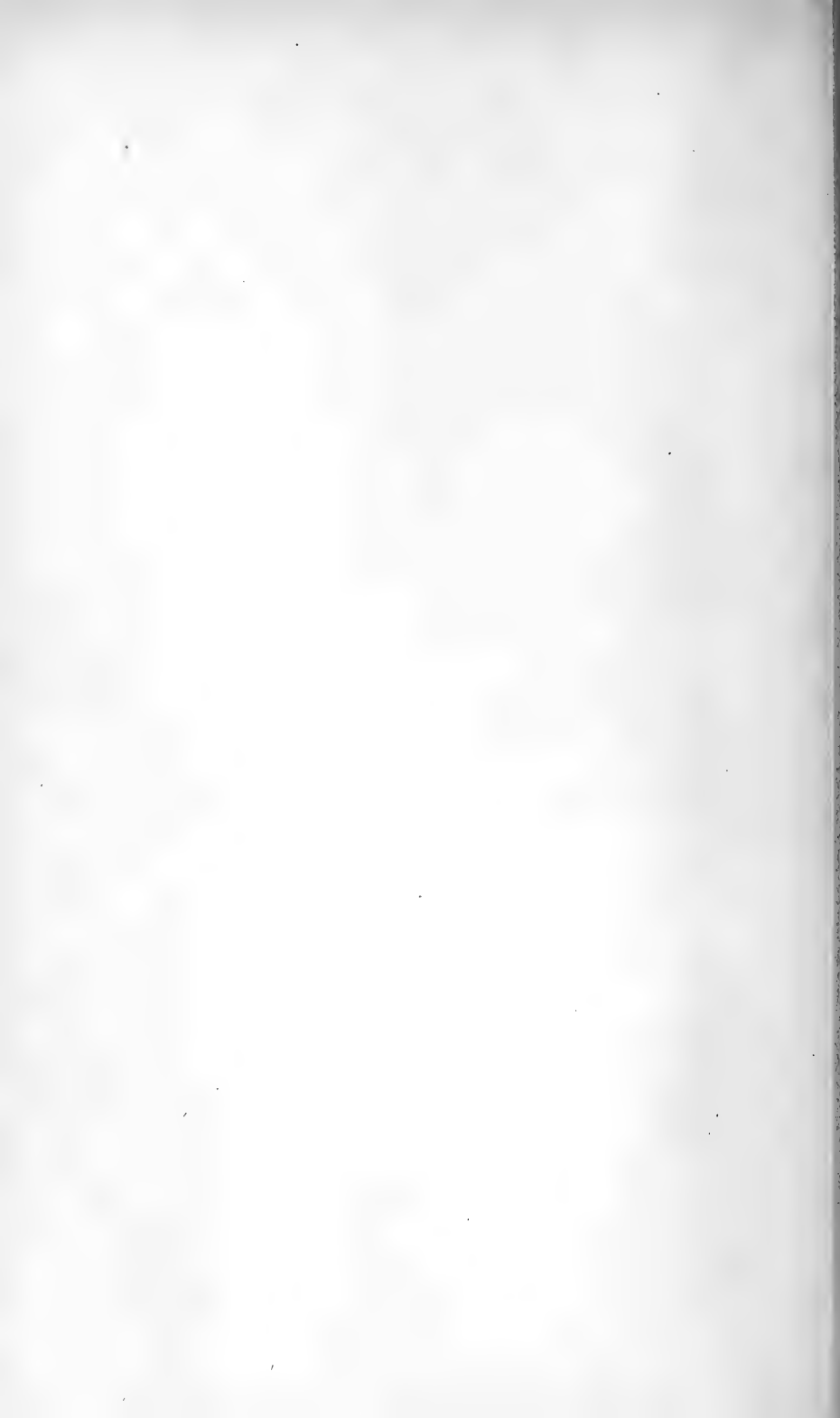


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19. *The TERTIARY BASALT-PLATEAUX of NORTH-WESTERN EUROPE.* By Sir ARCHIBALD GEIKIE, D.Sc., LL.D., F.R.S. (Read December 18th, 1895.)

[PLATES XV.-XIX.]

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# INTRODUCTION.

SINCE the publication, seven years ago, of my memoir on 'The History of Volcanic Action during the Tertiary Period in the British Isles,'<sup>1</sup> I have continued the investigation of this subject. My researches in this interval have included a re-examination of various tracts in Mull, Rum, Raasay, and Skye; numerous traverses in the last-named island, especially over areas which had not been previously described by any geologist; a detailed survey of Canna and its adjacent islets; an exploration of the Shiant Isles and other insular outliers of the Tertiary sills, and a visit to St. Kilda for the purpose of accurately determining the relations of its two great groups of igneous rocks. In two successive years I have prolonged my excursions into the Faroe Islands, where the phenomena of our basaltic plateaux are reproduced on a colossal scale, and where the numerous fjords and sounds have laid bare the most stupendous range of geological sections. This extended series of observations, while entirely confirming the main conclusions announced in my former memoir, has furnished many fresh and important illustrations of phenomena already described, and some new and interesting additions to our knowledge of the volcanic history of Tertiary time over the North-west of Europe. I now lay before the Society an outline of the chief results which have thus been obtained.<sup>2</sup>

<sup>1</sup> Trans. Roy. Soc. Edin. vol. xxxv. (1888) pp. 21-184.

<sup>2</sup> It is a pleasure to acknowledge the great assistance which has been kindly afforded to me in these researches. I am specially indebted to my friend Mr. Henry Evans, who, by placing his steam-yacht *Aster* at my disposal, enabled me to visit many localities among the Inner Hebrides and outer islands which are not easily accessible, and to make acquaintance with the whole group of the Faroe Islands. His brother, Col. John Evans, photographed for me

As the literature of the subject was fully summarized in my former memoir, it need not be further referred to here. Such more recent papers as bear on any of the localities which I shall have to describe, or on any of the questions I shall discuss, will be cited as the occasion arises.

### I. THE PLATEAU-LAVAS.

Every tourist who has sailed along the cliffs of Antrim, Mull, Skye, or the Faroe Islands is familiar with the singular terraced structure of the great volcanic escarpments which stretch as mural precipices along these picturesque shores. Successive sheets of lava, either horizontal or only gently inclined, rise above each other from base to summit of these walls, as parallel bars of brown rock with intervening strips of bright green grassy slope.

The geologist who for the first time visits these coast-lines is impressed by the persistence of the same lithological characters giving rise to the same topographical features. He soon realizes that the plateaux, so impressively truncated by the great escarpments that spring from the edge of the sea, are built up essentially of dark lavas,—basalts, dolerites, and andesites,—and that fragmental volcanic accompaniments, though here and there well developed, play on the whole a quite insignificant part in the structure and composition of those thick piles of volcanic material. Closer examination in the field enables him to ascertain that, regarded as rock-masses, the lavas include four distinct types:—

(1) Thick, massive, prismatic or rudely-jointed sheets, rather more coarsely crystalline and obviously more durable than the other types—inasmuch as they project in tabular ledges and tend to retain perpendicular faces, owing to the falling away of slices of the rock along the lines of vertical joint. Many rocks of this type are undoubtedly intrusive sheets, and as such will be further referred to in a later part of this paper. But the type includes also true superficial lavas which show the characteristic slaggy or vesicular bands at their upper and lower surfaces. The mere presence of such bands may not be enough, indeed, absolutely to establish that the rock possessing them flowed at the surface as a lava, for they are occasionally, though it must be confessed rarely, exhibited by true sills. But the rough scoriaceous top of a lava-stream, the presence of fragments of this surface in the overlying tuff, or wrapped round by the next succeeding lava sufficiently attest the true superficial outflow of the mass.

(2) Slaggy or amygdaloidal lavas without any regular jointed structure, but often with roughly scoriform upper and under layers, and tending to decay into brown earthy débris. Some of the upper

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many points of geological interest met with in our cruises. The pleasant hospitality of Mr. Thom, the proprietor of Canna, enabled me to survey in great detail on the 6-inch map of the Ordnance Survey the deeply interesting geology of his island-home, and to revisit Hysgeir, while Miss Thom took photographs for me of some of the more striking geological features of Canna and Sanday.

surfaces of such sheets among the Tertiary basalt-plateaux must have resembled the so-called 'Aa' of the Sandwich Islands. A striking example of the structure may be noticed at Camas Tharbernish, on the northern coast of the island of Canna. There the hummocks on the upper surface of a slaggy basalt measure about 15 feet in breadth, and rise about 3 feet above the hollows between them like a succession of waves (see fig. 1, p. 334). The steam-holes are disposed in a general direction parallel to the strike of the hummocks.

Great variety obtains in the size and shape of the vesicles. Huge cavities a foot or more in diameter may occasionally be found, and from such an extreme every gradation may be traced down to minute pore-like vacuoles that can hardly be made out even with a strong lens. In regard to the deformation of the vesicles, it is a familiar general rule that they have been drawn out in the direction of the flow of the original lava. Occasionally this elongation has advanced so far that the cavities have become straight, narrow pipes, several inches long, and only an eighth of an inch or so in diameter. A number of such pipes, arranged parallel to each other, resembles a row of worm-burrows. Remarkable illustrations of such extreme mechanical deformation by the movement of a still molten rock may be collected in Mull and Skye.<sup>1</sup>

It is a common belief that the filling-in of the steam-cavities has taken place long subsequent to the volcanic period by the slow percolation of meteoric water through the rocks. I believe, however, that at least in some cases, if not in all, the conversion of the vesicular lavas into amygdaloids was effected during the volcanic period. Thus it can be shown that the basalts which have been disrupted by the gabbros were already amygdaloidal before these basic intrusions disturbed them, for the kernels of calcite, zeolite, etc., have shared in the general metamorphism induced in the enclosing rock. Again, the blocks of amygdaloid contained in the agglomerates of the volcanic series are in every respect like the amygdaloidal lavas of the plateaux. It would thus seem that the infilling of the cavities with mineral secretions was not merely a long secular process of infiltration from the cool atmosphere, but was more rapidly completed by the operation of warmer water, either supplied from volcanic sources or heated by the still high temperature of the cellular lavas into which it descended from the surface.<sup>2</sup>

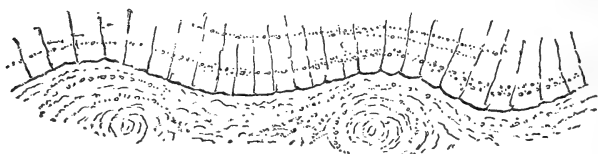
<sup>1</sup> Some examples have been deposited by me in the Museum of Practical Geology, Jermyn Street, in the case illustrating rock-structures. The elongation of the vesicles into annelid-like tubes may be observed among the stones in the volcanic agglomerates.

<sup>2</sup> Messrs. Harker and Marr have demonstrated that the Lower Silurian vesicular lavas of the Lake District had already become amygdaloids before the uprise of the Shap Granite, *Quart. Journ. Geol. Soc.* vol. xlix. 1893. J. D. Dana, originally an advocate of infiltration from above, subsequently supported the view here adopted, that the kernels of amygdaloids were filled in by the action of moisture within the rocks during the time of cooling (*Am. Journ. Sci.* ser. 3, vol. xx. 1880, p. 331).

Except in the elongation of the vesicles in one general direction, the amygdaloidal basalts seldom display any distinct trace of flow-structure. Occasionally, however, a striking exhibition of this structure may be seen among them. Thus at the top of the Dun Can, the highest summit of the island of Raasay, a small outlier of the plateau-lavas is capped with a black olivine-basalt, having a strongly-pronounced vesicular structure, wherein the cavities are filled with zeolites. The weathered faces of this rock show rudely parallel, puckered, and broken lines that mark the layers of devitri-fication in the original flowing lava.

(3) Prismatic or columnar basalts, which, as at the Giant's Causeway and Staffa, have long attracted notice as one of the most notable topographical elements in the structure of the plateaux. Though generally rather compact, becoming indeed dense, almost vitreous rocks in some sheets, they are often more or less cellular throughout, and highly slaggy along their upper and under surfaces. In some cases, as in that of a prismatic sheet which overlies the rough scoriaceous lava of Camas Tharbernish just referred to, the rows of vesicles are disposed in lines parallel to the under surface of the sheet (fig. 1).

Fig. 1.—*Section of scoriaceous and prismatic basalts. Camas Tharbernish, northern shore of Canna Island.*



As I have already remarked with regard to the massive, rudely-jointed sheets, many of the most perfectly columnar rocks of the plateaux are not superficial lavas, but intrusive sills, bosses or dykes. Conspicuous examples of the sills are displayed on the coast of Trotternish in Skye, of the bosses and dykes at the eastern end of Canna. To these further reference will be made in the sequel. It is not always possible to be certain that columnar sheets which are regularly intercalated among the undoubted lavas of the volcanic series may not be really intrusive. In some instances, indeed, we can demonstrate that they are so, when, after continuing perfectly parallel with the lavas above and below them, they eventually break across them. One of the most remarkable examples of this feature is supplied by the great sill of the south-west of Stromö in the Faroe Islands, of which I shall give some account in a subsequent section of this paper (figs. 9, 24, & 25, pp. 345, 380, 381).

(4) Banded or stratiform lavas, consisting of successive parallel layers or bands which weather into projecting ribs and flutings. The deceptive resemblance to sedimentary rocks thus produced



has no doubt frequently led to these lavas being mistaken for tuffs. As I have recently found them to be much more plentiful than I had supposed, a more detailed description of them seems to be required.

The banded character arises from marked distinctions in the texture of different layers of a lava-sheet. In some cases these distinctions arise from differences in the size of the crystals or in the disposition of the component minerals of the rock; in others, from the varying number and size of the vesicles, which may be large or abundantly crowded together in some layers, and small or only sparsely developed in others. The structure thus points to original conditions of the lava at the time of its emission, and may be regarded as, to some extent, a kind of flow-structure on a large scale.

Where the banding is due to differences of crystalline texture, the constituent feldspars, augites, and iron-ores may be seen even with the naked eye as well-defined minerals along the prominent surfaces of the harder ribs, while the broader intervening flutings of finer material show the same minerals in minuter forms. The alternating layers of coarser and finer crystallization lie, on the whole, parallel with the upper and under surfaces of the sheets in which they occur. But they likewise undulate like the streaky lines in ordinary flow-structure.

Banded structure of this type may be seen well developed in the lower parts of the basalt-plateaux throughout the Inner Hebrides and the Faroe Islands. A specimen taken from the western end of the island of Sanday, near Canna, which showed the structure by a conspicuous parallel fluting on weathered surfaces, was sliced for microscopical examination. My colleague, Mr. Alfred Harker, to whom I am indebted for the notes on the microscopic characters of rocks described in the present paper, has been kind enough to supply me with the following observations regarding this slice:—

‘In the slice [6660]<sup>1</sup> the banding becomes less conspicuous under the microscope. The rock is of basaltic composition, and, with reference to its micro-structure, might be styled a fine-grained olivine-diorite or olivine-dolerite in some parts of the slice, an olivine-basalt in others. It consists of abundant grains of olivine, imperfect octahedra and shapeless granules of magnetite, little simple or twinned prisms of labradorite, and a pale brown augite. The last-named mineral is always the latest product of consolidation, but it varies in habit, being sometimes in ophitic patches moulded upon or enclosing the other minerals, sometimes in small granules occupying the interstices between the feldspars and other crystals. The ophitic habit predominates in the slice, while the granitic comes in especially along certain bands. If the former be taken as indicative of tranquil conditions, the latter of a certain amount of movement in the rock during the latest stages of its consolidation, the banding, though not strictly a flow-structure, may be ascribed

<sup>1</sup> The figures within square brackets throughout this paper refer to the numbers of the microscopic slides in the Geological Survey (Scotland) collection, where I have deposited all those prepared from my specimens.

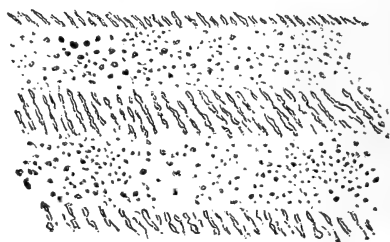
in some degree to a flowing movement of the nearly solidified rock. There is, however, more than this merely structural difference between the several bands. They differ to some extent in the relative proportions of the minerals, especially of olivine and augite; which points to a considerable flowing movement at an early stage in a magma which was initially not homogeneous.'

Where the banding arises from the distribution of the vesicles, somewhat similar weathered surfaces are produced. In some instances, while the basalt is throughout finely cellular, interposed parallel bands of harder, rather finer-grained and less thoroughly vesicular characters serve to give the stratified appearance. Instances may be observed where the vesicles have been crowded together in certain bands, which consequently weather out differently from the layers above and below them. An excellent illustration of this arrangement occurs in the lowest lava but one of the largest of the three picturesque stacks known as Macleod's Maidens, on the western coast of Skye. This lava is thoroughly amygdaloidal, but the vesicles are specially crowded together in certain parallel bands from 1 to 3 or 4 inches thick. Some of

these layers lie close to each other, while elsewhere there may be a band of more close-grained, less vesicular material between them. But the most singular feature of the rock is to be seen in the shape and position of the vesicles that are crowded together in the cellular bands. Instead of being drawn out into flattened forms in the general direction of banding, they are placed together at high angles. Each layer remains parallel to the general bedding, but its vesicles are steeply inclined in one direction, which doubtless indicates the flow of the still unconsolidated lava. Weathering along these bands, the lava might easily be mistaken at a little distance for a tuff or other stratified intercalation.<sup>1</sup>

Banded lavas possessing the characters now described are of frequent occurrence among the Inner Hebrides. Many striking examples of them may be seen along the western coast of Skye. Still more abundant in Faroe, they form one of the most conspicuous features in the geology of that group of islands. Along the whole of its western seaboard, on island after island, they are particularly prominent in the lower parts of the precipices, while the upper parts consist largely of amorphous or prismatic sheets. So much do they resemble stratified rocks that it was not until I had landed at

Fig. 2.—*Banded amygdaloidal basalt showing layers of elongated and steeply inclined vesicles. Macleod's Maidens, Skye.*



<sup>1</sup> This elongation of vesicles more or less perpendicular to the general bedding may be noticed sometimes even in sills, as will be shown farther on.

various points that I could satisfy myself that they are really banded lavas.<sup>1</sup>

On a first inspection any one of the great basalt-precipices seems to consist of regularly persistent sheets, which are continued from headland to headland, like strata of sandstone or limestone. I have dwelt on the deceptive nature of this apparent continuity, and have shown that when more closely examined these cliffs contain many proofs that, while the general bedding of the basalts is prolonged with much regularity, individual sheets may be seen to die out or to begin. I have insisted that these cessations do not occur in any general direction, that they furnish no evidence of any great central vents from which the lavas proceeded, but that on the contrary they show the eruptions to have probably taken place from many scattered vents and in every direction.

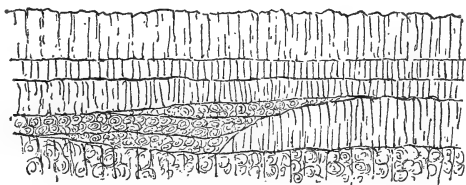
My recent journeys have furnished many additional proofs of the truth of this generalization. Closer scrutiny of the western cliffs of Skye last year, and again this summer, has brought to light numerous examples of the gradual or rapid disappearance of lava-beds, now in one direction, now in another. I may especially cite the great headland south of Talisker Bay, which reaches a height of 400 feet, and where, in the pile of nearly horizontal sheets, two beds may be seen to die out, one towards the north, the other towards the south. Farther north, in the cliff of the Hoe of Duirinish, 759 feet high, a similar structure presents itself. Owing to their greater exposure of bare rock, the sea-walls of the Faroe Islands furnish even more striking examples of discontinuity. On the western side of Suderö, lenticular beds of basalt form a conspicuous feature in the precipices that stretch northward from the highest headland. On Stromö the same structure occurs. Similar features arrest the attention on the precipices of Sandö, where, though at first sight the basalts seem to be regular and continuous, a nearer view of them reveals such sections as that shown in fig. 3, p. 338, where a group of sheets rapidly dies out towards the north against a thicker band that thins away in the opposite direction. Farther north we come upon other examples in the range of low cliffs between Kirkebonaes and Thorshaven, and more impressive still in the rugged precipices that face the Atlantic on the western front of Hestö (fig. 4, p. 338), where the disappearance is in a northerly direction.

But it is in the northern part of the Faroes, where the basalt-plateau has been so deeply trenched by parallel fjords as to be broken up into a group of long, narrow, lofty, and precipitous insular ridges, that the really local and non-persistent character of

<sup>1</sup> It is not necessary to give here a synopsis of the geological literature of the Faroe Islands. I may, however, refer to some recent papers, particularly to one by Prof. James Geikie (Trans. Roy. Soc. Edin. vol. xxx. 1880, p. 217); one by Prof. A. Helland (Dansk. Geografisk Tidsskr., 1881); R. Bréon, 'Notes pour servir à l'Etude de la Géologie de l'Islande et des Iles Féroë,' 1884; and one by Mr. J. Lomas, Proc. Geol. Soc. Liverpool, vol. vii. (1895) p. 292. Various writers have treated of the petrography, particularly A. Osann, Neues Jahrb. 1884, vol. i. p. 45. and Bréon. Banded lavas are noticed by J. Geikie, *op. cit.*

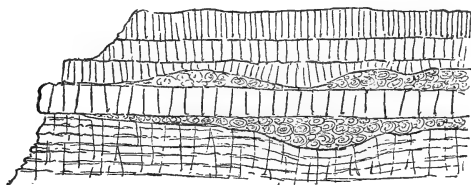
the lavas can best be seen. The eastern cliffs of Svinö present admirable examples, where in the same vertical wall of rock some of the basalts die out to the south, others to the north, while occasionally a shorter sheet may be seen to disappear in both directions as if it were the end of a stream that flowed at right angles to the others (fig. 5, below).

Fig. 3.—*Dying out of lava-beds, eastern side of Sandö, Faroe Isles.*



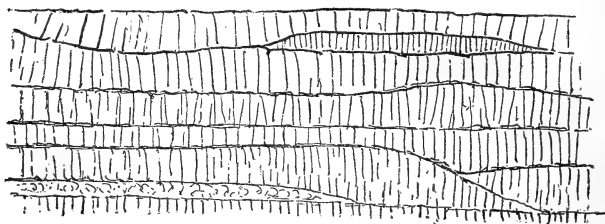
The islands of Kalsö and Kunö display the most impressive scenery of the plateau-basalts of Faroe. In these northern climes vegetation spreads less widely over rock and slope than it does in

Fig. 4.—*Lenticular lavas, western front of Hestö, Faroe Isles.*



the milder air of the Inner Hebrides. Hence the escarpments sweep as vast walls of almost bare rock from the level of the sea up to the serrated crests of the islands, some 2000 feet in height. Each individual bed of basalt can thus be followed continuously

Fig. 5.—*Lenticular lavas, eastern side of Svinö, Faroe Isles.*



along the fjords, and its variation or disappearance can be readily observed. Coasting along these vast natural sections, we readily perceive that the successive sheets of basalt have proceeded from no one common centre of eruption. They die out now towards one

quarter, now towards another, yet everywhere retaining the universal regularity and gentle inclinations of the whole volcanic series.

These bare rocky fronts, while permitting us to observe the want of continuity in many of the basalts, likewise afford an opportunity of following any particular sheet over the whole of its outcrop. I was particularly struck by the persistence of a dark band of basalt in the lower part of the western declivity of Kunö. This sheet can be kept in sight along the whole length of the island, at least from a point opposite to Mygledahl in Kalsö, with the exception of a short concealed space of detritus at the mouth of the recess behind the village of Kunö. It may possibly be even prolonged into the island of Borö, for a similar band is seen occupying the same position there. Its length on Kunö must be at least 6 nautical miles.

The more the basalt-plateaux of Britain and the Faroe Islands are studied, the more certain does the conclusion become that these widespread sheets of lava never flowed from a few large central volcanoes of the type of Etna or Vesuvius, but were emitted from innumerable minor vents or from open fissures. In a later part of this paper a number of the vents, which may still be seen under the overlying sheets of basalt, will be described, and I shall point out their resemblance to modern volcanic vents on the great lava-fields of Iceland.

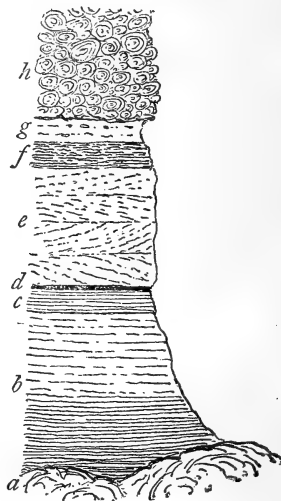
In looking at one of the sea-cliffs of the Inner Hebrides or of the Faroes, and in following with the eye its successive sheets of lava in orderly sequence of level bands from the breaking waves at the base to the beetling crest above, we are apt to take note only of the proofs of regularity and repetition in the outflows of molten rock and to miss the evidence that these outflows did not always rapidly follow each other, but were separated by intervals of varying, sometimes even of long, duration. The layer of red bole or decomposed lava, so often observable between the flows, has long been regarded as evidence of the lapse of an interval sufficiently extended to permit of considerable subaerial decay of the surface of a lava-sheet before the outflow of the next lava. But an attentive study of the plateaux discloses other and even more remarkable indications that the pauses between the consecutive basalt-beds were frequently so prolonged as to allow of extensive topographical changes being made in a district.

The occurrence, for example, of interstratifications of different kinds of sedimentary material among the lavas sufficiently demonstrates the reality of these intervals of quiescence. Where this material consists merely of volcanic tuff, it may only point to a continuance of volcanic activity in the form of fragmentary discharges during pauses in the outpourings of molten rock. In general, however, there is not only tuff but non-volcanic sediment arranged in definite layers, that show the action of running water. The various clays (bauxite, lithomarge, etc.) and ironstones which lie between the basalts of Antrim, besides their geological interest, have now considerable economic importance. The clays, in particular, are much in request as sources for the manufacture of aluminium. Neither among the Western Isles of Scotland nor in

the Faroes has any one definite platform yet been traced out on which such clays are extensively developed. But various minor and perhaps more local deposits in these regions might be examined as possibly available for industrial purposes. One of the most promising localities lies on the western side of Skye, at the mouth of Loch Bracadale, where, on the face of the great cliff of Rudha nan Clach, some conspicuous bands of lilac and red are interspersed among the basalts. These bands were noticed by Macculloch, who described them as varieties of 'iron-clay.'<sup>1</sup> I have not had an opportunity of examining them, except from the sea at a little distance. But they suggest a similarity to some of the variegated clays between the upper and lower basalt series of Antrim. The coal-bearing platform of the Faroes might also be followed along its outcrop, with the object of ascertaining whether any local deposits of similar clays exist there.

As an illustration of the diversity of deposits sometimes observable between the basalts, I give here a section exposed on the eastern side of Suderö in the Faroe Islands—a locality often visited and described in connexion with its coal-seams (fig. 6). At the base lies a sheet of basalt (*a*) with an irregularly lumpy upper surface. It may be remarked that the group of basalts below this stratified intercalation is marked by the occurrence of numerous columnar sheets, some of them possibly sills, and also more massive, solid, and durable basalts than the sheets above. The lowest of the intercalated sediments are light-coloured clays, passing down into dark nodular mudstone and dark shale, the whole having a thickness of at least 20 feet (*b*). These strata are succeeded by (*c*) pale clays with black plant-remains, about 3 feet thick. Immediately above this band comes the coal or coaly layer (*d*), here about 6 inches thick, which improves in thickness and quality farther inland, where it has been occasionally worked for economic purposes. A deposit of green and brown volcanic mudstone (*e*), 12 feet in thickness, overlies the coal and passes under a well-bedded granular green tuff and mudstone 3 feet thick (*f*). The uppermost band is another volcanic mudstone (*g*) 4 feet in thickness, dark green in colour, and more or less distinctly stratified, with irregular concretions, and also pieces of wood. Above this layer comes another thick overlying group of basalts (*h*) distinguished by their abundantly amygdaloidal

Fig. 6.—Section at Frodbonyp, Suderö.



<sup>1</sup> 'Description of the Western Islands of Scotland,' vol. i. (1819) p. 376.

character, and by their weathering into globular forms which at a little distance give them a resemblance to agglomerates.

We have here an intercalated group of strata upwards of 40 feet thick, consisting partly of tuffs and partly of fine clays, which may either have been derived from volcanic explosions or from the atmospheric disintegration of basaltic lavas. Through some of these strata abundant carbonaceous streaks and other traces of plants are distributed, while among them lies a band almost wholly composed of compressed vegetation. Unfortunately none of the strata at this locality seem to have preserved the plant-remains with sufficient definiteness for identification. There can be no doubt, however, that they were terrestrial forms like those of Mull and Antrim.

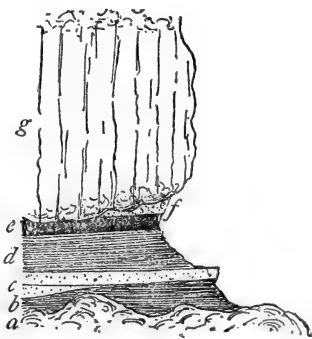
This coal, with accompanying sedimentary deposits, has been traced through Suderö, and another outcrop, possibly of the same horizon, occurs on Myggenaes, the extreme western member of the Faroe group, at a distance of some 40 miles.<sup>1</sup>

Though good coal is not well developed in the Tertiary volcanic plateaux of the British Isles, I have found coaly layers to be extremely abundant there. And as the vegetable matter may confidently be assumed always to indicate terrestrial vegetation, the presence of these carbonaceous bands may be regarded as good evidence of some lapse of time between the eruption of the basalts which they separate. I have observed that they not infrequently form the highest member of a group of intercalated sediments between two sheets of basalt. This relation is strikingly exhibited in the isle of Canna in connexion with the river-gravels, to which more detailed reference will be made in a later part of this paper. But I may here cite an interesting example which occurs at the base of the lofty sea-cliff of An Ceannaich, to the south of Dunvegan Head, on the western coast of Skye (fig. 7).

At the base of the precipice ledges of a highly amygdaloidal basalt (*a*) show a singularly scoriaceous and amygdaloidal structure, with abundant and beautiful zeolites, the hollows of the upper surface of the sheet being filled in with dark brown carbonaceous shale, forming a layer from 1 to 14 inches thick, marked by coaly streaks and lenticles (*b*). A band of green and yellow sandstone (*c*) next supervenes, which, from its pale colour, attracts attention from a distance, and led me, while yachting along the coast, to land at the locality, in the

hope that it might prove to be a plant-bearing limestone. This

Fig. 7.—*Intercalated group of strata between basalts. An Ceannaich, western coast of Skye.*



<sup>1</sup> See in particular J. Geikie, Trans. Roy. Soc. Edin. vol. xxx. (1880) p. 229.

sandy stratum is only some 3 or 4 inches thick at the northern end of the section, but increases rapidly southward to a thickness of as many feet or more, when, owing to the cessation of the underlying shale, it comes to lie directly on the amygdaloid and to enclose slaggy portions of that rock. Immediately above the sandstone 2 or 3 feet of fissile shale, black with plant-remains (*d*), include brown layers that yield to the knife like some oil-shales. The next stratum is a seam of coal (*e*) about 1 foot thick, of remarkable purity. It is glossy, hard, and cubical, including layers that break like jet. It has been succeeded by a deposit of green sand (*f*), but while this material was in course of deposition another outpouring of lava took place, whereby the terrestrial pool or hollow in the lava-field in which the group of sedimentary materials accumulated was filled up and buried. This lava is about 20 feet thick, and consists of a coarsely-crystalline, jointed dolerite with highly amygdaloidal upper and under surfaces. Its slaggy bottom has caught up or pushed aside the layer of green sand, so as to lie directly on the coal, and has there been converted into that earthy modification so familiar under the name of 'white trap' among our coal-fields. It is interesting to find that this kind of alteration, where molten rock comes in contact with carbonaceous materials, is not confined to subterranean sills, but may show itself in lavas that have flowed over a terrestrial surface.

From the frequent intercalation of such local deposits of sedimentary material between the basalts we may reasonably infer that during older Tertiary time the rainfall in North-western Europe was copious enough to supply many little lakes and streams of water. As the surface of the lava-fields decayed into soil, vegetation spread over it, so that perhaps for long intervals some tracts remained green and forest-clad. But volcanic action still continued to show itself, now from one vent, now from another, these wooded tracts were buried under overflows of lava, and, the watercourses being filled up, their streams were driven into new channels, and other pools and lakes were formed. Some of the evidence for this part of the volcanic history will be given in the IIIrd section of the present paper.

## II. THE VENTS.

Though the abundant vents, which, to judge from the lenticular nature of the lavas, were dotted over the surface of the Tertiary volcanic plains, have for the most part been buried under sheets of molten material, the progress of denudation has laid bare some of them. It is chiefly along the coast-line that this process of excavation has successfully taken place. The interior of the islands is often loaded with peat, covered with herbage, or strewn with glacial detritus; and even where indications of the vents are there to be detected, it is not always possible to ascertain the true limits and connexions of these old volcanic chimneys. But where the structure of the plateaux has been laid bare along ranges of rocky precipice, the vents have sometimes been so admirably dissected by the sea that



every feature of their arrangement can be satisfactorily determined. In the memoir already cited I have described a number of examples from the interior. I now proceed to give an account of other instances from the coast-sections.

I will begin with a group of vents in the Faroe Islands which display with singular clearness some of the most characteristic features of this part of the volcanic record. And here let me remark that, although these islands have been so frequently visited and so often described that their general structure is sufficiently well known, they present in their details so vast a mass of new material for the illustration of volcanic action that they deserve a far more minute and patient survey than they have yet received. They cannot be adequately mapped and understood by the traveller who merely sails round them. They must be laboriously explored, island by island and cliff by cliff. While I cannot pretend to more than a mere general acquaintance with their structure, I have learnt by experience that one may sail near their precipices and yet miss some essential features of their volcanic structure. Last year I passed close to the noble range of precipices on the western side of Stromö, at the mouth of the Vaagöfjord, and sketched the sill which forms so striking a part of the geology of that district (figs. 24 & 25, pp. 380, 381). But I failed to observe an even more remarkable and interesting feature at the base of the same sea-cliffs. This last summer, probably under better conditions of light, I was fortunate enough to detect with my field-glass, from the deck of the yacht, what looked like a mass of agglomerate. Steaming inshore I was delighted to find, as the vessel drew nearer to the cliff, that the agglomerate assumed definite boundaries and occurred in several distinct patches, until at last it presented the unmistakable outlines of a group of vents underlying and overspread by the bedded basalts of the plateau. I at once got into the longboat, and, favoured by an unusually calm sea, was enabled to steer into every nook and round every buttress and islet of this part of the coast-line.

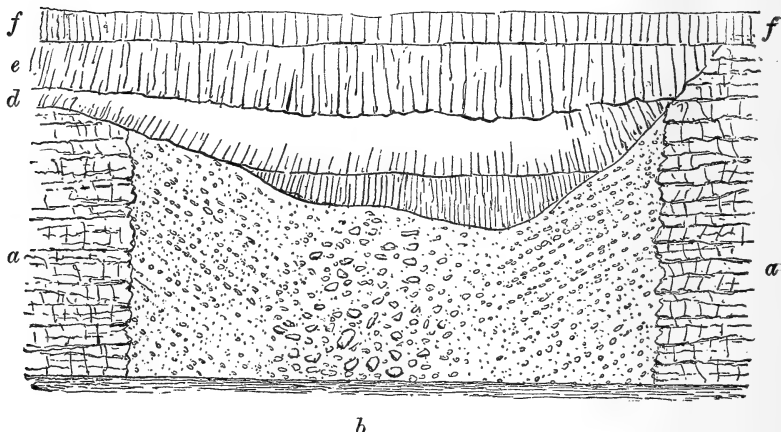
The basalt-plateau here presents to the western ocean a nearly vertical escarpment which must reach a height of at least 1000 feet (see fig. 24, p. 380), and displays a magnificent section of the bedded lavas. The lower part of this section shows chiefly the banded structure already described, the layers of different consistency being etched out by the weather in such a way as to give them the look of stratified rocks. In the upper part of the precipice columnar and jointed or prismatic sheets are more common, but the most prominent band is the great sill just alluded to, and to which further reference will be made in the sequel.

In the course of the gradual retreat of the cliff, as the waves tunnel its base and slice after slice is detached from its vertical front, a group of at least five small vents has been uncovered lying along a nearly north-and-south line. Of two of these a segment remains still on the cliff-wall and passes under the basalts; the others have been dissected and half cut away from the cliff, while groups of stacks and rocky islets of agglomerate may mark the

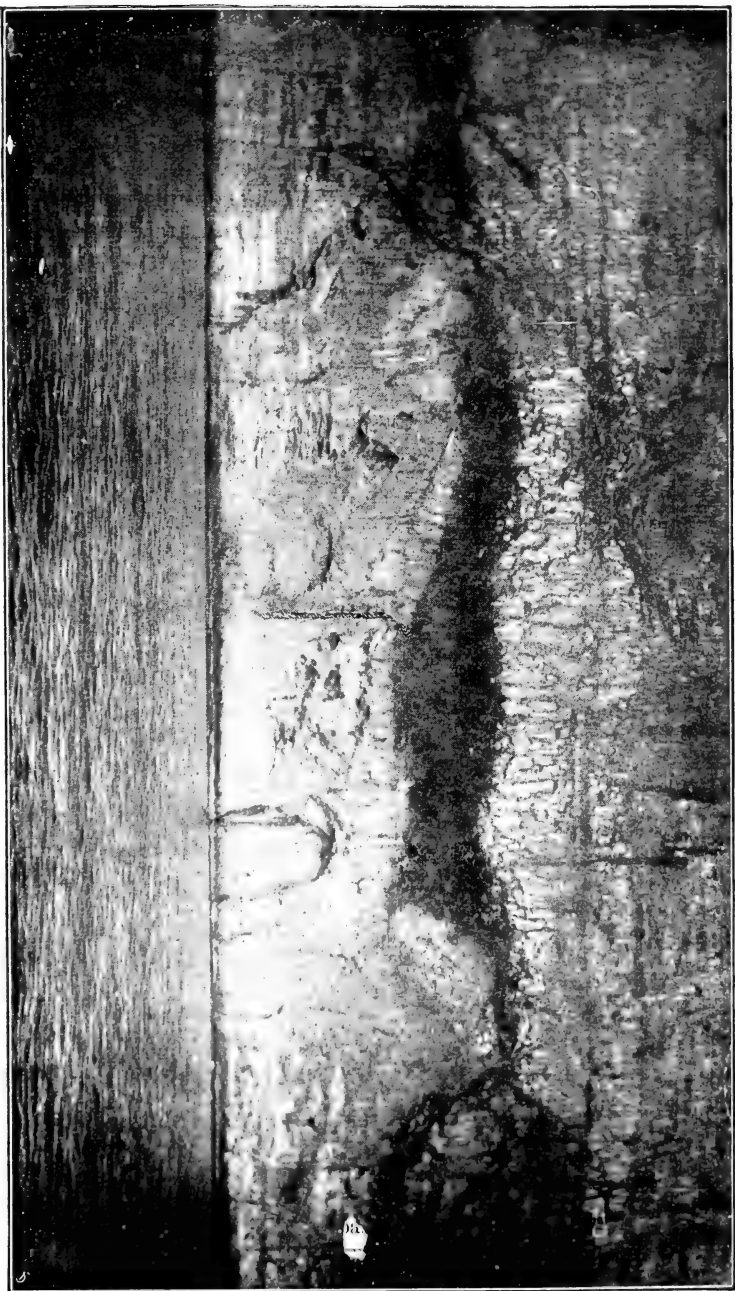
positions of others almost effaced. The horizontal distance within which the vents are crowded is probably less than half a mile, but the lofty proportions of the precipice tend to lead the eye to underestimate both heights and distances.

The agglomerate is a thoroughly volcanic rock, consisting of blocks of all sizes of various basalts, among which large slags are specially conspicuous, the whole being wrapped in a granular matrix of comminuted volcanic detritus. The arrangement of this material is best seen in the fourth vent (Pl. XV. and fig. 8). In this characteristic

Fig. 8.—Section of the same neck as that shown in Pl. XV.



volcanic neck (*b* in fig. 8) the boundary walls, as laid bare on the face of the precipice, are vertical, and are formed of the truncated ends of the banded lavas (*aa*) which have been blown out at the time of the formation of the orifice. The visible diameter of the vent was roughly estimated by me to be about 100 yards. No appreciable alteration was observed in the ends of the lavas next the vent. The agglomerate is coarsest in the centre, where huge blocks of slaggy lava lie imbedded in the amorphous mass of compacted débris. On either side of this structureless central portion the agglomerate is distinctly stratified from the walls towards the middle, at angles of  $30^{\circ}$  to  $35^{\circ}$ . Even from a distance it can be observed that the upper limit of the agglomerate is saucer-shaped, the sloping sides of the depression dipping towards the centre of the neck at about the same angle as the rudely stratified agglomerate underneath. From the bottom of this basin to the sea-level may be a vertical distance of some 30 yards. The basin itself has been filled up by three successive flows of basalt, of which the first has merely overflowed the bottom, the second (*d*), entering from the northern rim of the basin, extends across to the southern slope, while the third (*e*), also flowing from the north, has filled up the remainder of the hollow and extended completely across it. The next succeeding lava (*f*) stretched over the site in such a way



VOLCANIC NECK PIERCING AND OVERLAIN BY THE PLATEAU-BASALTS, STROMÖ, ENTRANCE OF VAAGÖFJORD, FAROE ISLANDS.  
(From a photograph by Col. JOHN EVANS.)

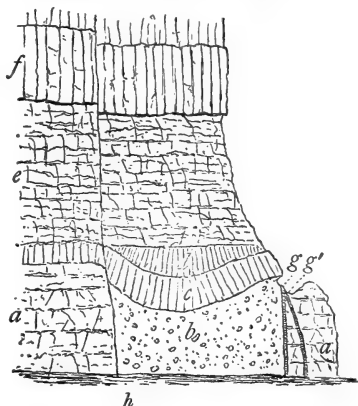


as to bury it entirely, and to provide a level floor for the piling up of the succeeding sheets of basalt.

The second vent, which is represented in fig. 9, exhibits the same features, but with some additional points of interest.

It measures roughly about 20 yards in diameter at the sea-level, rises through the same group of banded basalts (*aa*), and is filled with a similar agglomerate (*b*). Its more northerly wall is now coincident with a line of fault (*h*) which ascends the cliff, and probably marks some subsidence after the eruptions had ceased. The southern wall shows that a dyke of basalt (*g*) has risen between the agglomerate and the banded basalts, and that a second dyke (*g'*) traverses the latter at a distance

Fig. 9.—Volcanic neck close to that shown in Pl. XV. & fig. 8.



of a few feet. In this instance, also, the upper surface of the agglomerate forms a cup-shaped depression which has been filled in by two successive streams of lava (*c*, *d*). Among the succeeding lavas (*e*) a prominent sill (*f*) has been intruded, to which more special reference will be made in the sequel.

These necks are obviously volcanic vents belonging to the time of the basaltic eruptions. They have been drilled through the basalts of the lower part of the cliff, but have been buried under those of the central and higher parts. The arrangement of their component materials in rude beds dipping towards the centre of the vent shows that the ejected dust and stones must have fallen back into the orifice so as to be rudely stratified towards the centre of the chimney, which was finally closed by its own last discharges of coarse detritus. The saucer-shaped upper limit of the agglomerate seems to indicate that after the eruptions ceased each vent remained as a hollow or *maar* on the surface of the lava-fields. And the manner in which they are filled with successive sheets of basalt shows that in course of time other eruptions from neighbouring orifices gave forth streams of lava which, in flowing over the volcanic fields, eventually buried and obliterated each of the vents.

In the destruction of the precipice some of the vents have been so much cut away that only a small part of the wall is left, with a portion of the agglomerate adhering to it. The third neck, for instance, affords the section represented in fig. 10, p. 346, where the horizontal sheets of basalt (*a*) have still a kind of thick pellicle of the volcanic detritus (*b*), adhering to what must have been part of the side of the orifice of eruption. The waves have cut out a cave at the base, so that one can, by boat, get behind the agglomerate and see the margin of the volcanic funnel in the roof overhead.

In the fragment of geological history so picturesquely laid bare on the Stromö cliffs we are presented with a significant illustration of what seems to have been a common type of volcanic vent in the Tertiary basalt-plateaux. By the fortunate accident that denudation has not proceeded too far, we are able to observe the original tops of at least two of the vents, and to see how such volcanic orifices, which were doubtless abundant all over these plateaux, came to be entombed under the ever-increasing pile of accumulating basalt.

There is still one feature of interest in these cliff-sections which deserves notice here. Every geologist who has studied the composition of the basalt-plateaux has remarked the comparatively insignificant part played by tuffs in these volcanic accumulations. Hundreds of feet of successive basalt-sheets may often be examined without the discovery of any intercalation of fragmental materials, and even where such intercalations do occur they are for the most part quite thin and extremely local. I found it impossible to scale the precipice for the purpose of ascertaining whether around the Stromö vents, and connected with them, there might not be some beds of tuff interstratified between the basalts. If such beds exist, they can be of only trifling thickness and extent. Here, then, are examples of once active vents, the funnels of which are still choked up with coarse fragmentary ejections, yet from which little or no discharge of ashes and stones took place over the surrounding ground. They seem to have been left as *maare* or crater-like hollows on the surface of the lava-fields.

The next example of a neck which I will describe occurs on the cliffs that form the southern side of the sheltered inlet known as Portree Bay in the Isle of Skye. These cliffs, the seaward escarpment of the basalt-plateau, rise above a platform of Jurassic sandstones and shales. At Camas Garbh, where they have been trenched by a small rivulet, aided by the presence of two dykes, the gully thus formed exposes a section of a neck of agglomerate that underlies the basalts of the upper half of the cliff. This neck is connected with a thick deposit of volcanic conglomerate and tuff which, lying between the basalts, extends from the neck to a considerable distance. The general relations of the rocks in this cliff are represented in fig. 11.

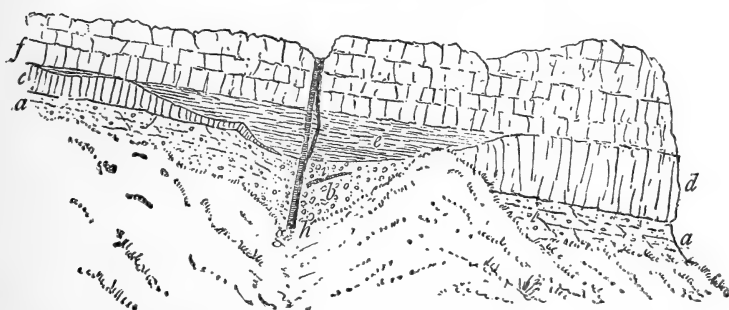
The agglomerate (*b* in fig. 11) is quite tumultuous, and here and there strikingly coarse. Some of its included blocks measure 5 feet in length. These fragments represent most of the varieties of the lavas of the district. Large slaggy masses are abundant, and sometimes exhibit the annelid-like elongation of the vesicles

Fig. 10.—Section of wall of another neck of agglomerate in the same group with those represented in Pl. XV. & figs. 8, 9.



to which I have referred as occasionally displayed by the plateau-basalts. More than 60 feet of agglomerate is visible in vertical height from where its base is concealed by débris and vegetation to where its upper surface passes under a banded rock to be afterwards described. That this unstratified mass of volcanic ejectamenta marks the site of the vent can hardly be doubted, although denudation has not revealed the actual walls of the chimney. The steep grassy slopes do not permit of the relations of the rocks being everywhere seen, but the agglomerate appears to pass laterally into finer, rudely stratified material of a similar kind, which extends east and west of the vent as a thick deposit between the bedded

Fig. 11.—*Section of volcanic vent and connected lavas and tuffs.*  
*Scorr, Camas Garbh, Portree Bay, Skye.*



- a.* Rudely-bedded dull green tuff; *b.* Coarse agglomerate; *c.* Prismatic basalt; *d.* Massive jointed basalt; *e.* Red banded decomposing rock, probably of detrital origin; *f.* Plateau-basalts, prismatic and rudely columnar; *g.* Dyke of dolerite, somewhat vesicular, 5 to 6 feet broad; *h.* Basalt dyke 2 to 3 feet broad; *i.* Dyke or sill of basalt similar to *h.*, and possibly connected with it.

basalts. Possibly denudation has only advanced far enough to lay bare the crater and its surrounding sheets of fragmentary material, while the chimney lies still buried underneath.

East of the agglomerate the fragmentary material becomes less coarse, and shows increasing indications of a bedded arrangement. Close to the agglomerate the dip of the coarse tuff is towards that rock at about  $10^{\circ}$ . A few yards farther east a sheet of very slaggy basalt is seen to lie against the tuff, which it does not pierce. The vesicles in this adhering cake of lava have been pulled out in the direction of the slope till they have become narrow tubes 4 or 5 inches long and parallel to each other. Some parts of this rock have a curved ropy surface, like that of well-known Vesuvian lavas, suggestive of the molten rock having flowed in successive thin viscous sheets down the slope, which has a declivity of about  $30^{\circ}$ . This part of the section may possibly preserve a fragment of the actual inner slope of the crater, formed of rudely bedded tuffs.

Continuing still eastward, we find the feebly stratified tuff (*a*) to be perhaps 200 feet thick. It forms a grassy declivity that descends from the basalt-escarpment above to the grass-covered platform which overlies a lower group of basalts. The visible portion of this tuff presents a thoroughly volcanic character, being made up of the usual dull dirty-green granular paste, through which are dispersed angular and rough lumps of slag and pieces of more solid basalt varying up to 1 or 2 feet in length. These stones are generally disposed parallel to the indistinct bedding, but are sometimes placed on end as if they had assumed that position on falling from an explosive shower. Among the smaller stones, pieces of a finely vesicular basic pumice are frequent and are among the most strikingly volcanic products of the deposit. From a characteristic sample of these stones, a thin slice was prepared and placed in Mr. Harker's hands. The following are his observations on it:— 'A very compact dark-grey rock, amygdaloidal on a minute scale. The lighter grey crust is probably due merely to weathering, and the specimen seems to be a distinct fragment, not a true bomb.

'The slice [6662] shows it to be essentially a brown glass with only occasional microscopic crystals of a basic plagioclase. It has been highly vesicular, and the vesicles are now filled by various secondary products, including a chloritic mineral, nearly colourless and singly refracting in thin section, and a zeolite.'

Tracing now the tuff from the western side of the vent, we can follow it to a greater distance. No abrupt line can be detected here, any more than on the other side between the agglomerate and the tuff. The latter rock extends under the overlying plateau of basalt, at least as far west as Portree Loch, a distance of fully a mile, but rapidly diminishes in thickness in that direction. Traces of what is probably the same tuff can be detected between the basalts at Ach na Hannait, more than 3 miles to the south. It is thus probable that from the Portree vent fragmentary discharges took place over an area of several square miles.

Above the agglomerate of this vent two lavas may be seen to start towards opposite directions. One of these (*c* in fig. 11) begins immediately to the east of the two dykes. It is a dull prismatic basalt with a slaggy bottom, its vesicles being pulled out in the direction of the general bedding of the section. It descends by a twist or step, and then lies on the gently inclined surface of the tuff which dips towards the agglomerate. Farther east it increases in thickness and forms the lowest of the basalt-sheets of the cliff. The lava that commences on the western side of the vent (*d* in fig. 11) is a massive jointed basalt, which, though not seen at the vent, appears immediately to the west of it and rapidly swells out so as to become one of the thickest sheets of the locality. It lies upon the rudely bedded tuff, and is covered by the other basalts of the cliff.

That these two basalts came out of this vent cannot be affirmed. If they did so at different times, their emission must have been followed by the eruption which cleared the funnel and left the



central mass of agglomerate there. But that some kind of saucer-shaped depression was still left above the site of the vent is indicated by the curious elliptical mass of rock (*e*) that lies immediately above the agglomerate from which it is sharply marked off. This is one of the most puzzling rocks in the district, probably in large measure owing to its advanced state of decay. It is dull red in colour and decomposes into roughly parallel layers, so that at a short distance it looks like a bedded tuff, or like some of the crumbling varieties of banded lavas. I could not obtain specimens fresh enough to put its nature and origin beyond dispute. Whatever may have been its history, this ferruginous rock rests in a saucer-shaped depression lying directly above the agglomerate of the vent. The form of this depression, like that of the Faroe necks, corresponds fairly well with what we may suppose to have been the final position and shape of the crater of the little volcano. The rock that occupies the hollow dies out towards the east on the face of the cliff, and the prismatic basalt (*c*) is then immediately covered by the rest of the basalt-sheets of the plateau (*f*). On the western side its precise termination is concealed by grass. But it must rapidly dwindle in that direction also, for not many yards away it is found to have disappeared, and the basalts (*d* and *f*) come together.

Though the decayed state of this rock does not warrant any very confident opinion regarding its history, I am inclined to look upon it as a deposit of much disintegrated volcanic detritus washed into the hollow of the old crater when it had become filled with water, and had passed into the condition of a *maar*. The peculiarly oxidized condition of its materials points probably to long atmospheric exposure, and an examination of the surrounding parts of the district furnishes more or less distinct evidence that a considerable lapse of time did actually intervene between the cessation of the eruptions of the Portree volcano and the next great basalt-floods of this part of Skye.

That volcanic eruptions from other vents continued after this Portree example had become extinct is proved by the great sheets of basalt (*f*) that overspread it and still bury a large tract of the fragmentary material which it discharged. At a later time a fissure that was opened across the vent allowed the uprise of a basalt dyke (*g*), and subsequently another injection of similar material took place along the same line of weakness (*h* and *i*).

Before leaving this interesting locality we may briefly take note of the distribution of the ashes and stones ejected by the volcano, and the evidence for the relative length of the interval between the outflow of the lavas below and that of those above the tuff and volcanic conglomerate. Admirable sections of these deposits may be traced along the base of the cliffs for a mile to the west of the vent. They thin away so rapidly in that direction that at a distance of  $\frac{3}{4}$  mile they do not much exceed 50 feet in thickness. At Camas Bàn they consist mainly of a fine, dull-green, granular, rudely stratified basalt-tuff, through which occasional angular

pieces of different lavas and rough slags are irregularly dispersed. These stones occur here and there in rows, suggestive of more vigorous discharges, the layers between the platforms of coarser detritus being occupied by fine tuff. Some of the ejected blocks are imbedded on end—an indication of the force with which they were projected and fell nearly a mile from the crater.

The upper parts of the tuff pass upward into fine yellow, brown, and black clays a few feet in thickness, the darker layers being full of carbonaceous streaks. On this horizon the coal of Portree was formerly mined. The workings, however, have long been abandoned, and, owing to the fall of large blocks from the basalt-cliff overhead, the entrance to the mine is almost completely blocked up. One wooden prop may still be seen keeping up the roof of the arch, which is here a slaggy basalt.

East and south-east of the Portree vent, extensive landslips of the volcanic series and of the underlying Jurassic formations make it hardly possible to trace the continuation of the tuff-zone in that direction. To the south, however, at a distance of rather more than 3 miles, what is probably the same stratigraphical horizon may be conveniently examined from Ach na Hannait for some way to the north of Tianavaig Bay. At the former locality the calcareous sandstones of the Inferior Oolite are unconformably covered by the section represented in fig. 12. At the bottom of the volcanic series lies a sheet of nodular dolerite with a slaggy upper surface (a). Wrapping round the projections and filling up the depressions of this lava comes a thin group of sedimentary strata from 1 or 2 to 18 inches or more in thickness (b). These deposits consist of hardened shale charged with macerated remains of linear leaves and other plant-remains, including and passing into streaks of coal, which may be looked upon as probably occupying the same horizon with the coal of Portree. But here, instead of reposing on a mass of stratified tuff, the carbonaceous layers lie on one of the bedded lavas. The tuff has died out in the intervening 3 miles, yet that some of the discharges of volcanic detritus reached even to this distance, and that they took place during the accumulation of these layers of mud and vegetation is shown by the occurrence in the shales of pieces of finely amygdaloidal basalt from less than 1 to 6 inches in length, likewise of lapilli of a fine, minutely cellular, basic pumice, like some varieties of palagonite. The overlying dolerite (c) becomes finely prismatic at its

Fig. 12.—Section of the volcanic series at Ach na Hannait, south of Portree, Skye.







PART OF A VOLCANIC NECK AT THE EASTERN END OF THE ISLAND OF CANNA.  
(See also fig. 15.) (From a photograph by Miss THOM, of Canua.)

junction with the sedimentary layers, and has probably indurated them.

This intercalation of a shaly and coaly band among the lavas can be followed northward along the coast. In some places it has been invaded by dykes, sills, and threads of basalt on the most remarkably minute scale, of which I shall give some account in a later part of this paper (see fig. 21, p. 375). North of Tianavaig Bay—that is, about  $\frac{3}{4}$  mile nearer to the Portree vent—a perceptible increase in the amount of volcanic material is observable among the shales and leaf-beds. Not only are lapilli of basic pumice abundant, but the volcanic detritus has accumulated here and there in sufficient amount to form a band of dull greenish-brown tuff.

I have already alluded to the characteristic fact that the interstratifications of sedimentary material among the basalt-plateaux frequently terminate upward in leaf-beds, thin coals, or layers of shale, full of indistinctly preserved remains of plants, and some further striking illustrations of this feature will be described from the river-shingles and other evidences of water-action during the volcanic period in the islands of Canna and Sanday. There cannot be any doubt that the vegetation thus preserved was terrestrial. It probably grew not far from the sites where its remains have been preserved. Leaves and seeds would naturally be blown or washed into pools on the lava-fields, and would gather there among the mud and sand carried by rain from the surrounding ground. Such a topography and such a sequence of events point to intervals of longer or shorter duration between the successive outpourings of basalt. It was probably during one of these intervals of quietude that the crater of the Portree volcano became a *maar*, and was finally silted up.

There is one last example of a volcanic vent, of which a description may here be given. It occurs at the eastern end of the island of Canna. A portion of it projects from the grassy slopes, and rises vertically above the beach as a picturesque crag in front of the precipice of Compass Hill (Pl. XVI.). But the same rock may be traced southward to the Coroghon Mòr, and north-westward in the lower part of the cliffs to a little beyond the sea-stack of An Stòll. It has thus a diameter of at least 3000 feet. Westward it passes under the conglomerate to be afterwards described, and its eastern extension has been concealed by the sea.

The materials that fill this vent consist of a typical agglomerate composed entirely, or almost entirely, of volcanic detritus. The imbedded blocks vary up to 8 feet in diameter or even more. They are chiefly fragments of various basalts and andesites, generally vesicular or amygdaloidal. Some of these, which have evidently been broken off already consolidated lavas, are angular or sub-angular in shape, and their steam-holes are cut across by the outer surfaces of the stones. Where filled with calcite, zeolite, etc., the amygdules so exactly resemble those of the bedded basalts of the

plateaux that, as already remarked, we must believe them to have been already filled by infiltration before the disruption of the rocks by volcanic explosions. Other blocks are true bombs, with a fine-grained crust outside and a more cellular texture inside, the vesicles of the outer crust being sometimes dragged round the surface of the stone. The variety of materials included among the ejected blocks and the abundance of pieces of the red bole which so generally separates the plateau-basalts indicate that a considerable thickness of bedded lavas has probably been broken through by the vent. Besides the volcanic materials, occasional angular pieces of red (Torridon) sandstone may be observed in the agglomerate. The paste is a comminuted mass of the same material as the blocks, tolerably compact, and entirely without any trace of stratification.

The actual margin of this vent has nowhere been detected by me. We never reach here the base of the volcanic series, for it is sunk under the sea-level. On the other hand, the upper limits of the agglomerate have been partially effaced or obscured by the thick conglomerates which overlie it. There can be no doubt, from the breadth of ground across which the agglomerate can be followed along the shore, that the vent must have been one of somewhat exceptional size, perhaps not less than  $\frac{3}{4}$  mile in diameter, unless, indeed, there were more than one in close proximity. That it continued in vigorous eruption may be judged from the amount of material ejected from it, the large size of its blocks, and the distance to which they were sometimes thrown.

The pieces of Torridon Sandstone were no doubt derived from the extension of that formation underneath Canna. On the opposite island of Rum these pre-Cambrian red sandstones are copiously developed. They form there a platform through which the Tertiary volcanic series has been erupted. Several remaining outliers of the bedded basalts on the western side of that island show that the basalt-plateau of Small Isles once covered that area, and that it rested immediately on the inclined edges of the Torridon Sandstone. Probably the same structure stretches westward under Canna and Sanday. No traces of any Jurassic strata have been detected beneath the volcanic rocks of Rum, though they are so well developed a few miles to the east in the island of Eigg. Either they were not deposited over the pre-Cambrian rocks of Rum, or they had been removed from that ancient ridge before the beginning of the Tertiary volcanic period. Certainly I have not detected a single recognizable fragment of any Jurassic sedimentary rock in the agglomerate of Canna.

This Canna vent exhibits, better than is usually shown, the occurrence of dykes and irregular injections of lava through the agglomerate. A large mass of a finely columnar basalt ascends from the beach at Garbh Asgarnish. A similar rock forms several detached crags a little farther south, particularly in the headland of Coroghon Mòr and the island of Alman. Here the basalt is

beautifully columnar, its slender prisms curving from a central line until their ends abut against the agglomerate. The truly intrusive character of this basalt is well shown on the southern front of Coroghon Mòr, and on the northern face of Alman, as represented in the accompanying diagrams (figs. 13 & 14).

Although there is no conclusive evidence that these intrusions belong to the time of the activity of the vent, yet they differ so much from the ordinary dykes (one of which also cuts the agglomerate and ascends through the conglomerates and basalts above), are confined so markedly to the vent and its immediate proximity, and resemble so closely the basalt-injections of other vents, such as those of the Carboniferous and Permian necks of Scotland, that they may with every probability be regarded as part of the mechanism of the Canna volcano.

Though the form and size of the vent of this volcano cannot be precisely defined, the upper part of its agglomerate is dovetailed in the most interesting way with a series of coarse conglomerates, which indicate strong aqueous action in this part of the volcanic area during the time of the eruption of the plateau-basalts. As the history of the eruptions of the Canna vent is so closely linked with that of some

powerful river which flowed across the lava-fields in this part of Western Scotland, I reserve further account of it for the next section of this paper.

Fig. 13.—*Columnar basalt invading agglomerate of volcanic vent. Coroghon Mòr, Isle of Canna. (Height more than 20 feet.)*

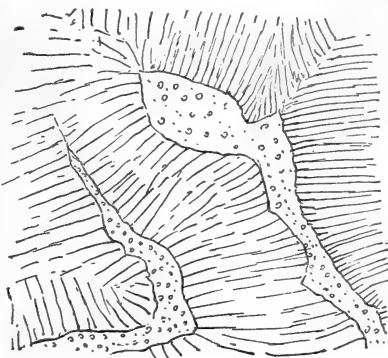
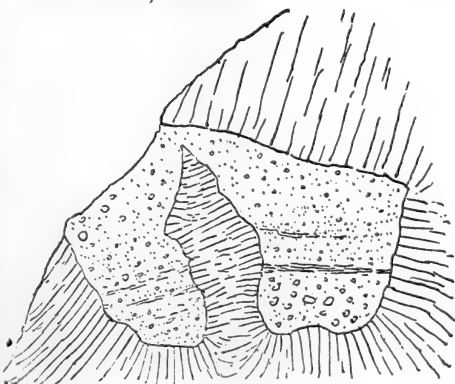


Fig. 14.—*Columnar basalt invading volcanic conglomerate. Northern side of Alman Islet, Canna.*



## III. THE RIVERS OF THE VOLCANIC PERIOD.

Many years ago I communicated to this Society an account of an ancient river-channel which, during the volcanic period, had been eroded on the surface of the basalt-plateau, and of which a small portion had been preserved under a stream of pitchstone-lava that had flowed into and buried it.<sup>1</sup> This watercourse, now marked by the picturesque ridge of the Scur of Eigg, was shown to have been excavated by a stream which came from the north-east or east, and to be younger, not only than the plateau-basalts of the district, but younger even than the dykes which cut these basalts. Yet that it belonged to the volcanic period was proved by the manner in which it had been sealed up and preserved under the black glassy lava of the Scur.

Within the last two years I have met with other and more abundant evidence of river-action in the same region of the Inner Hebrides. This evidence, however, belongs to an earlier part of the volcanic period. It reveals that a powerful river, flowing westward from the Highland mountains, swept over the volcanic plain, while the sheets of basalt were still being poured forth, and while volcanic eruptions were taking place from cones of slag.

This interesting record is preserved in the islands of Canna and Sanday. The gravels and silts of the river are there found intercalated between the basalts, mingled with volcanic detritus, probably ejected from the active vent already described. On visiting these islands for the first time last year, I found so much that was new to me in regard to the history of Tertiary volcanic action, and which demanded a careful survey, that I returned to the locality this summer and remained in Canna until I had mapped that island and its dependencies upon the Ordnance Survey sheets on the scale of 6 inches to a mile.

Macculloch, in his account of Canna and Sanday, took notice of the intercalation of beds of conglomerate among the basalts. He regarded these detrital rocks as having been arranged under water and as marking pauses in the deposition of the sheets of 'trap.' He likewise gave two diagrams in illustration of the relations of the conglomerates, but he expressed no definite opinion as to the origin of these rocks, though in one passage he seems to have inclined towards the belief that they were formed in the sea.<sup>2</sup> Since his time, so far as I am aware, no fresh light has been thrown upon the subject.

The conglomerates are best developed at the eastern end of Canna, where the cliffs present the structure illustrated in fig. 15. At the base, and passing under the level of the sea, lies the agglomerate (*a*) of the vent already described. This rock has a somewhat uneven upper surface, which rises in places about 150 feet above high-tide mark. Here and there it shades off upward into

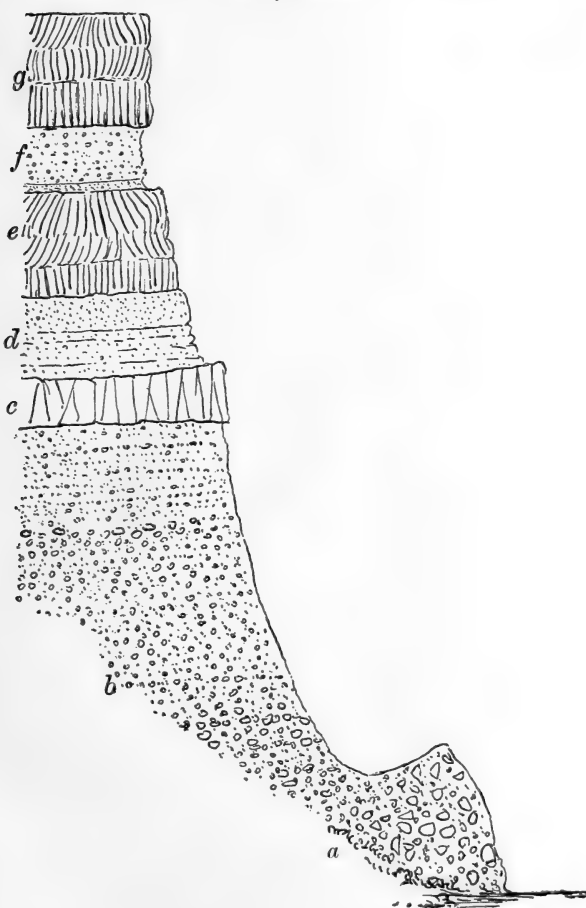
<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 303.

<sup>2</sup> 'Description of the Western Islands,' vol. i. (1819) pp. 449, 457, pl. xix. figs. 2 & 3.



the conglomerate that overlies it; waterworn pebbles appear among its contents, and rude traces of bedding begin to show themselves, until, within the course of a few feet, we pass upward into an undoubted conglomerate. Elsewhere, however, and particularly along the precipices west of Compass Hill, the two deposits are

Fig. 15.—*Section of the cliffs below Compass Hill,  
Isle of Canna.*



more distinctly marked off from each other. The agglomerate has there a hummocky, irregular upper surface, as if it had been thrown down in heaps. The hollows between these protuberances have been filled up with conglomerate and sandstone, forming the base of the thick overlying deposits.

It is thus clear that the loose materials of the vent were directly exposed at the surface when the conglomerate was accumulated, and, indeed, that these materials served to supply some of the detritus of which the conglomerate consists. The absence of any trace of a cone and crater at the vent may perhaps be explicable on the supposition that their incoherent material was washed down by the currents that swept along and deposited the conglomerate.

The mass of sedimentary material (*b*) which overlies the agglomerate of the vent forms a conspicuous feature along the lower half of the precipices at the eastern end of Canna. It rises to a height of 250 to 300 feet above sea-level, and must reach a maximum thickness of probably not less than 100 to 150 feet. It gradually descends in a westerly direction both along the northern cliffs and in the lower ground round Canna Harbour, insomuch that in about a mile, owing to the gentle westerly dip of the whole volcanic series, combined with the effect of a number of small faults, it passes under the level of the sea.

Great variation in the character of the detritus composing this thick group of strata may be observed as it is followed westward. On the cliffs below Compass Hill, as represented in fig. 15, p. 355, a coarse conglomerate with waterworn stones, hardly to be distinguished from the volcanic agglomerate of the vent, shows more or less distinct bedding, or at least a succession of coarser and finer bands. Towards its base it encloses numerous pieces of Torridon Sandstone, sometimes subangular, but often so well and smoothly rounded as to show that they must have been long subjected to the action of moving water. It is further observable that, while in the agglomerate the volcanic stones have rough surfaces, those in the conglomerate begin to show increasing evidence of attrition, until, as the deposit is traced upward, they become almost as well rounded and waterworn as the non-volcanic stones which have come from another district.

Yet amidst and overlying these proofs of transport from some little distance lie abundant huge slags and blocks of amygdaloidal lava, sometimes closely aggregated, sometimes scattered through a volcanic tuff or ashy sandstone. The composition and structure of these stones, and the manner of their dispersion through the deposit, leave little doubt that they were ejected from the vent. We are thus confronted with the interesting fact that, while the materials of the volcanic cone were being washed down by running water, eruptions were still taking place. But by degrees these indications of contemporaneous volcanic activity disappear. The detrital materials become coarser and more distinctly water-rolled, until they pass into greenish sandstones and fine conglomerates. Yet the matrix even of these higher sediments is largely composed of fine volcanic detritus, and probably points to occasional discharges of dust and ashes.

Various sills or intrusive sheets have been injected into this sedimentary group along the precipices at the eastern end of Canna, and form there lenticular bands. One of these (*c*) is shown in fig. 15.

Immediately above the massive greenish pebbly sandstone (*d*) which caps the stratified series, lies a group of basalts (*e*), composed of several distinct beds, having a united thickness of from 80 to 100 feet. The lowest of these has a regular columnar structure, while those overlying it exhibit the confused starch-like grouping of curved and rather indistinctly-formed prisms, which is so characteristic a structure in the plateaux.

The next band in upward succession is one of conglomerate (*f*), which runs as a continuous and conspicuous feature along the upper part of the cliff. This rock presents in many respects a strong contrast to the conglomerates underneath. It is dull green to yellow in colour, and is well stratified, being marked by the interstratification of finer layers, and passing down into a band of pebbly sandstone, which rests immediately on the basalt (*e*). Its component stones are thoroughly waterworn, ranging up to 6 inches or even more in length. But its most distinctive character lies in the nature of its pebbles. Instead of consisting mainly of volcanic materials, these stones have almost all been transported for some distance. They include abundant fragments of Torridon Sandstone, gneiss, schists, grits, and other rocks like those in Rum and Western Inverness-shire. No such rocks exist *in situ* in Canna. The nearest tract of Torridon Sandstone is in Rum, about 4 miles to the eastward. But the pieces of schist and epidotic grit, like the rocks of the Western Highlands, must have travelled at least 30 miles.

It is important to observe that all these transported stones indicate a derivation from some source lying to the eastward of Canna. The evidence in this respect agrees with that furnished by the ancient river-gravel under the pitchstone of the Scur of Eigg. It is clear that the waters which found their way across the lava-fields of this part of the Inner Hebrides took their rise among the mountains of Inverness-shire.

The conglomerate now described is from 40 to 50 feet thick. It can be followed along the face of the cliffs for more than a mile on the northern side of Canna. Less persistent on the southern side, its outcrop strikes from the edge of the precipice inland, keeping to the south of the top of Compass Hill. It is well seen in the ravine above the Coroghon, but cannot be followed farther westward among the basalt-terraces. Yet, though this stratified intercalation is not traceable very far as a band of conglomerate, the same stratigraphical horizon is probably indicated elsewhere by other kinds of sedimentary deposits, to which further reference will be made in the sequel.

The section now described establishes the existence of at least two successive platforms of conglomerate in the volcanic series. Following these platforms along their outcrop, we obtain additional light on their origin, and on the topographical conditions under which they were deposited, and we learn further that other prolonged intervals, which were likewise marked by intercalations of sedimentary material, occurred in the outpouring of the basalts.

Taking first the lower conglomerate of Compass Hill and tracing

it westward, we find that it forms the depression in which the sheltered inlet of Canna Harbour lies. It is exposed along the shores and also in the islands enclosed within the same bay. But it is not traceable farther west, possibly because it seems to sink beneath the level of the sea. To the south-east, though it is there likewise for the greater part concealed under the waves, it rises above them in one or two parts of the coast-line of Sanday, particularly at the Uamh Ruadh or Red Cave, and likewise on a surf-beaten skerry off Ceann an Eilein, the highest part of the Sanday cliffs—a distance of about  $1\frac{1}{2}$  mile from Compass Hill. Throughout this space it retains its remarkably coarse character, and is mainly made up of volcanic material.

The numerous sections exposed in Canna Harbour enable us to study the composition and local variations of this curious deposit. On the northern side of the basin, while the lower part of the sedimentary series continues to be an exceedingly coarse volcanic conglomerate, it passes upward into finer conglomerates, tuffs, and shales. In front of Canna House the imbedded blocks are of large size, occasionally as much as 3 or 4 feet in diameter. They are still more gigantic on Eilean a' Bhaird, where I found one to contain 150 cubic feet in the exposed part, the rest being still imbedded in the matrix. As they are generally somewhat rounded, here and there markedly so, most of these stones have probably undergone a certain amount of attrition in water. The great majority of them, and certainly all those of larger size, are pieces of basalt, dolerite, andesite, red bole, etc. Among them huge blocks of amygdaloid and coarsely vesicular lava are specially abundant. Some of these look like pieces of slag torn from the upper surface of lava-streams; others, displaying a highly vesicular centre and a close-grained outer crust, are suggestive of bombs. It is interesting to note here again that the amygdaloidal blocks present their zeolitic infiltrations so precisely like those of the amygdaloids of the plateaux, that it seems reasonable to suppose the carbonate of lime, zeolites, etc. to have been introduced before the blocks were imbedded in the conglomerate.

The whole aspect of this deposit is eminently volcanic. It looks like a vast sheet of lava-fragments swept away from one or more cones of slags and cinders, or from the rugged surface of a lava-stream. Where the vesicles were still empty, the large boulders could be more easily swept along by moving water. But a powerful current must have been needed to transport and wear down into more or less rounded forms blocks of basic lava, many of which must weigh several tons. The large block on Eilean a' Bhaird, for instance, probably exceeds 12 tons in weight.

Besides the obviously volcanic contents of the conglomerate there occur here also, as in the Compass Hill cliffs, abundant pieces of Torridon Sandstone. These stones are notably smaller in size and more perfectly waterworn and even polished than the blocks of lava. Obviously they have travelled farther and have undergone more prolonged attrition.

The matrix of the rock consists essentially of the fine detritus of

basic lavas, probably mingled with true volcanic dust. The coarser parts display only the feeblest indication of stratification; indeed, in a limited exposure the rock might be regarded as a tumultuous agglomerate. But the manner in which the deposit is intercalated with, and sometimes overlies, green tuffs and shales, together with the waterworn condition of its stones, shows that it has not been accumulated in a volcanic chimney, but has been thrown down by some powerful body of water, with probably the co-operation of volcanic discharges.

While the composition of the conglomerate suffices to indicate that it was accumulated at a time when some volcano was active in the immediate neighbourhood, singularly convincing proofs of the work of this vent are to be seen in the form of intercalated sheets of lava. Thus on Eilean a' Bhaird the boulders of the conglomerate are overlain and wrapped round by a sheet of rudely prismatic basalt, with lines of vesicles arranged in the direction of the bedding. A similar relation can be traced along the beach between Canna House and the wooden pier, where successive sheets of basalt have flowed over the conglomerate (see fig. 16, p. 361).

But, besides coarse volcanic detritus, the sedimentary platform represented by the lower conglomerate of Compass Hill includes other deposits of which good sections may be examined all round Canna Harbour. Beds of fine, well-stratified, dull green tuff pass by an admixture of pebbles into fine ashy conglomerate or pebbly sandstone, and by an increase in the proportion of their fine detritus into volcanic mudstone and fine shales. The shales vary from a pale grey or white tone into blackish grey, brown, and black. They are well stratified and are frequently interleaved with layers of fine tuff. The darker bands are carbonaceous, and are not infrequently full of ill-preserved vegetation. Indeed, leaves and stems in a rather macerated condition are of common occurrence in all the shaly layers. Here and there, especially in some ashy shales in front of Canna House, I observed a recognizable *Sequoia*. The mudstones are dull green, close-grained, shattery rocks composed of fine volcanic detritus, and pass both laterally and vertically into shales, tuffs, and conglomerates. They suggest showers of fine dust or streams of volcanic mud. They, too, contain fragmentary plants.

It is a noteworthy fact, to which reference has already been made, that the sedimentary intercalations among the Canna basalts generally end upward in carbonaceous shales or coaly layers. The strong currents and overflows of water, which rolled and spread out the coarse materials of the conglomerates, gave way to quieter conditions that allowed silt and mud to gather over the water-bottom, while leaves and other fragments of vegetation were blown or washed into these quiet reaches. Good illustrations of this sequence in the case of the lower conglomerate-zone of Canna may be studied along the shores of Sanday, from the Catholic Chapel eastward. The fine pebbly sandstones, tuffs, and shales, which there overlie the coarse conglomerate, are surmounted by dark brown or black carbonaceous shale with lenticles of matted vegetation that pass

into impure coal. Immediately overlying this coaly layer lies a sheet of prismatic vesicular basalt, followed by another with an exceedingly slaggy texture.

Lenticles of shale and mudstone likewise occur in the heart of the finer parts of the conglomerate, especially towards the top, as may be seen in the section exposed beneath the basalt behind the first cottage west from Canna House. One of the most interesting layers in this section is a seam of tuff varying up to about 2 inches in thickness, which lies at the top of the lenticular band of tuffs and shales, and immediately beneath the band of basalt-conglomerate, on which a basalt, carrying a vesicular band near its bottom, rests. Traced laterally, the dark brown tuff of this seam gradually passes into a series of rounded bodies and flattened shells composed of a colourless mineral which has evidently been developed *in situ* after the deposition of the tuff. Mr. Harker's notes on thin slices made from this band are as follows :—

‘This is a rusty brown, dull-looking rock, rather soft and seemingly light, but too absorbent to permit of its specific gravity being tested. The dark brown mass is in great part studded with little spheroidal bodies,  $\frac{1}{50}$  to  $\frac{1}{10}$  inch in diameter, of paler colour, but the larger ones having a dark nucleus. In other parts larger flat bodies have been formed, as if by the coalescence of the spheroids, extending as inconstant bands in the direction of lamination for perhaps  $\frac{1}{2}$  inch, with a thickness of  $\frac{1}{10}$  inch or less. The appearance is that of a spherulitic rather than an oolitic structure.

‘A slice [6658 A] shows the general mass of the rock to be of an extremely finely divided but coherent substance of brown colour, which can scarcely be other than a fine volcanic dust composed of minute particles of basic glass or ‘palagonite’ compacted together. Scattered through this are fragments of crystals recognizable as triclinic and perhaps monoclinic felspar, green hornblende, augite, olivine (?), and magnetite, usually quite fresh.

‘The curious spheroidal and elongated growths already mentioned are better seen in another slide [6658 B], where they occupy the larger part of the field, leaving only an interstitial framework of the brown matrix. The substance of the little spheroids is clear, colourless, and apparently structureless. The centre is often occupied by an irregularly stellate patch of brown colour, and sometimes cracks tend to run in radiating fashion, but these are the only indications of radial structure. The outer boundary is sharply defined, and where the slice is shattered the spheroids have separated from the matrix. The matrix is darker than in the normal rock, being obscured by iron oxide which we may conceive as having been expelled from the spaces occupied by the spheroids. The little crystal-fragments are enclosed in the spheroids as well as in the matrix, but there is no appearance of their having served as starting-points for radiate growths. The flat elongated bodies are like the spheroids, with merely the modifications implied in their different shape.

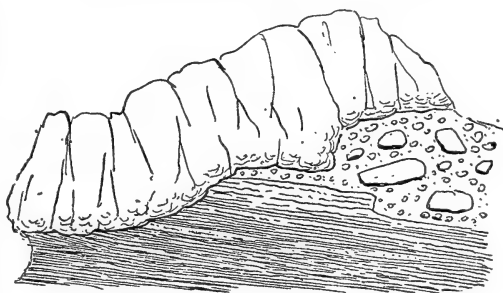
‘The identity of the clear colourless substance seems to be rather

doubtful. It is sensibly isotropic, and of refractive power distinctly lower than that of felspar. These characters would agree with analcime, which is not unknown as a contact-mineral; but it is difficult to understand how analcime, even a lime-bearing variety like that of Plas Newydd,<sup>1</sup> could be formed in abundance from palagonitic material. An alternative supposition, perhaps more probable, is that the clear substance is a glass, modified from its former nature especially by the expulsion of the iron oxide into the remaining matrix. A comparison is at once suggested with certain types of 'knotenschiefer,' but respecting the thermal metamorphism of fine volcanic tuffs there seems to be little or no direct information.'

Lenticular interstratifications of shale and mudstone make their appearance even in the coarser parts of the conglomerate, as may be observed on the

beach below Canna House where, as shown in fig. 16, some shales and tuffs full of ill-defined leaves are surmounted by a coarse conglomerate. The deposition of this overlying bed of boulders has given rise to some scooping-out of the finer strata underneath.

Fig. 16.—*Lava cutting out conglomerate and shale. Shore below Canna House.*



Subsequently both the conglomerate and the shales have been over-spread by a stream of dolerite, the slaggy bottom of which has ploughed its way through them.

Before discussing the probable conditions under which the group of sedimentary deposits now described was formed, we may conveniently follow the upper conglomerate-band of Compass Hill and note the variations in structure and composition which its out-crop presents.

This yellowish conglomerate can be traced along the cliffs for more than a mile, when it descends below the sea-level at the solitary stack of Bod an Stöl. A few hundred yards farther west, what is probably the same band appears again at the base of the precipice overlain by prismatic basalts. But the conglomerate, here only 12 feet thick, is made of much finer detritus which, largely composed of volcanic material, includes small, well-rounded and polished pebbles of Torridon Sandstone. Beneath it lies a bed of

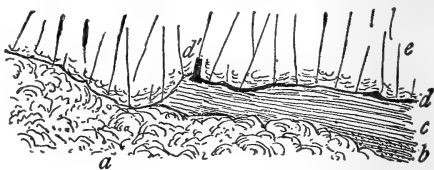
<sup>1</sup> Henslow, Trans. Camb. Phil. Soc. vol. i. (1822) p. 408; Harker, Geol. Mag. 1887, p. 414. Mr. W. W. Watts suggests a comparison with the hexagonal bodies figured by Mr. Monckton in an altered limestone from Stirlingshire, Quart. Journ. Geol. Soc. vol. li. (1895) p. 488.

dark shale, with remains of plants, resting immediately on a zeolitic amygdaloid which plunges into the sea. The chief interest of this locality is to be found in the shale which, instead of appearing at the top of the sedimentary stratification, lies at the bottom. I was informed by Mr. A. Thom that leaves had been obtained from this shale, but I was not successful in my search for them. The locality is only accessible by boat, and, as the coast is fully exposed to the Atlantic swell, landing at the place is usually difficult and often impossible.

About  $1\frac{1}{2}$  mile still farther west, where a foreshore fronts the precipice of Earnagream at the Camas Tharbernish, a band of intercalated sedimentary material underlies the great escarpment of basalts and rests upon the slaggy sheet with the singular 'aa' surface already referred to. This band not improbably occupies the same platform as the upper conglomerate of Compass Hill. It is only about 7 feet thick, the lower 4 feet consisting of a dull green pebbly tuff or ashy sandstone, with small rounded pieces of Torridon Sandstone, while the upper 3 feet are formed of dark shale with crowded but indistinct remains of plants. Here the more usual order in the sequence of deposition is restored. The shale is indurated and shattery, so that no slabs can be extracted without the use of quarrying-tools.

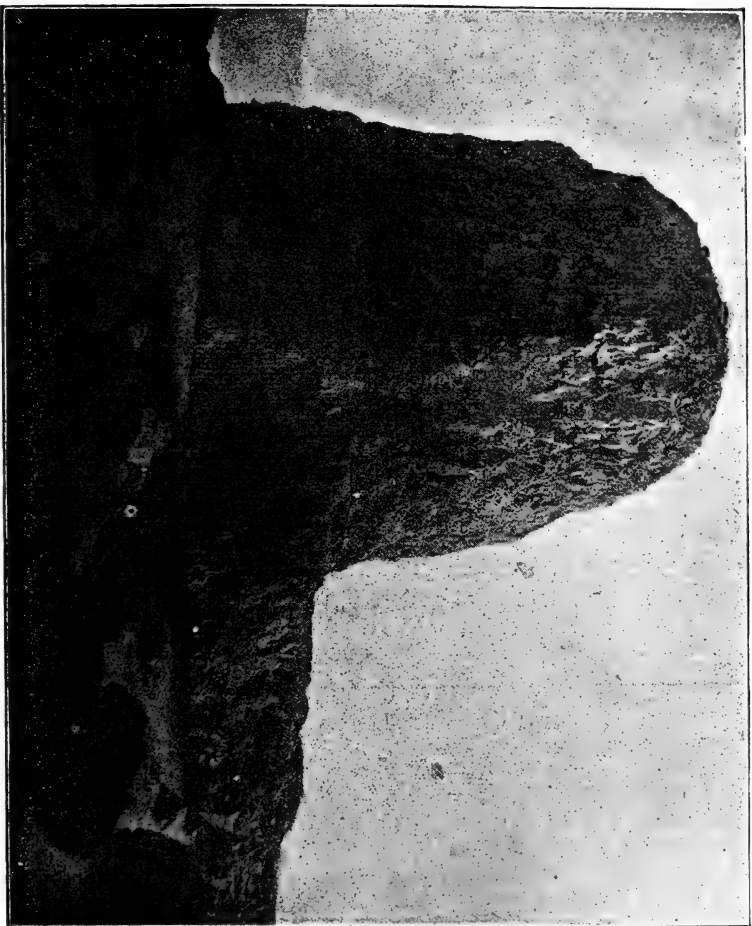
Rather less than  $\frac{1}{2}$  mile towards the south, on the roadside at the gully of Cùl nam Marbh, the basalts enclose a sedimentary interstratification which not improbably lies on the same horizon as those just described along the northern shore. The relations of the rocks at this locality are shown in fig. 17. A remarkably slaggy basalt (a) rises into a hummock against which have been deposited some fine granular tuffs (b), whereof only a few inches are visible, that pass up into a thin band of dark shale (c), including a layer of pebbly ferruginous tuff, with small rounded pea-like pieces of basalt, basic pumice,

Fig. 17.—Section of shales, tuffs, and a coniferous stump lying between two basalt-sheets. Cùl nam Marbh, Canna.



bole, limonite, etc. At the top of this shale an irregular parting of coaly material (d) lies immediately under the slaggy base of the succeeding basalt (e). It will be observed that this upper lava cuts out the shale and thus comes to rest directly upon the lower sheet. At the point where it begins to descend it has caught up and enclosed a small tree-stump (d') which stands upright on the coaly parting and shale. This stump, at the time of my visit, measured 5 inches in height by 3 inches in breadth; it had been thoroughly charred and was crumbling away on exposure, but among the pieces which I took from it sufficient trace of structure can be detected with the microscope to show the tree to have been a conifer.





DŪN MÓR, SANDAY. (From a photograph by Miss THOM, of Canina.)



We have here another instance of the deposition of volcanic dust and fine mud in a pool that filled a hollow in the lava-field. Again we see that the closing act of sedimentation was the washing of vegetable matter into the pool, which was finally buried under another outflow of basalt.

It is on the southern coast of the isle of Sanday that the higher intercalations of sedimentary material among the basalts are most instructively displayed. At the eastern end of this island, as already stated, the lowest and coarsest conglomerate is visible on a skerry immediately south of the headland of Ceann an Eilein. It doubtless underlies the Sanday cliffs, but is not there visible, for the basalts descend below sea-level. These volcanic sheets have a slight inclination westward; hence as we proceed in that direction we gradually pass into higher parts of the series. In the Creag nam Faoileann (Seamews' Crag) and the gully that cuts its eastern end, likewise in the two singularly picturesque stacks of Dùn Mòr and Dùn Beag (Big and Little Gull Rocks), which here rise from the foreshore, two distinct platforms of detrital material may be noticed among the basalts. Both of these can be well seen on Dùn Mòr, which is represented in Pl. XVII. The lower band, 4 or 5 feet thick, is here a rather coarse conglomerate, which lies upon a sheet of scoriaceous basalt that extends up to the base of the Creag nam Faoileann. It is directly overlain by another basalt, about 30 feet thick, which dips seaward and forms a broad shelving platform, whereon the tides rise and fall. On this stack a second coarse conglomerate, about 10 feet thick, forms a conspicuous band about a third of the height from the bottom; it is composed mainly of well-rounded blocks of various lavas up to 18 inches or more in diameter, but it contains also pieces of Torridon Sandstone. It is covered by about 60 feet of basalt, which towards the base is somewhat regularly columnar, but passes upward into the wavy, starch-like, prismatic structure.

If now we trace these two intercalated zones of conglomerate along the shore, we find that they both rapidly change their characters and disappear. The lower, though formed of coarse detritus under the Dùn Mòr, passes on the opposite cliff, in a space of not more than 60 yards, into fine tuff and shale, about 6 feet thick, which become carbonaceous at the top, where they are overlain by the next basalt. A hundred yards to the east the band likewise consists of tuffs and ashy shales, which underlie the basalts on the Dùn Beag, and again show the usual coaly layers at the top. On the eastern side of the gully in the coast, about 160 yards north-east of Dùn Mòr, the same band is reduced to not more than 3 feet in thickness, consisting chiefly of fine conglomerate, wherein well waterworn pebbles of Torridon Sandstone and epidotic grit appear among the predominant volcanic detritus. This conglomerate is surmounted by a few inches of dark carbonaceous mudstone or shale. Rough slaggy basalts lie above and below the band.

The upper conglomerate dies out, both eastward and westward, in the cliff opposite the Dùn Mòr, dwindling down at last to

merely a few pebbles between the basalts. It lies in a kind of channel or hollow among these lavas, which in an east-and-west direction cannot be more than about 65 yards broad.

Probably still higher in the series of basalts is another intercalation of sedimentary layers which may be seen in the little bay to the east of Tallabrig, rather more than a mile to the west of the Creag nam Faoileann. It rests upon a coarsely slaggy amygdaloid, and is from 6 to 10 feet in thickness. The lower and larger part of the deposit consists of greenish pebbly sandstone and fine conglomerate, largely composed of basaltic detritus, but including abundant well-smoothed and polished pebbles of Torridon Sandstone, green grit, quartzite, etc. The stones vary from mere pea-like pebbles up to pieces 2 or 3 inches long, the largest being generally fragments of slag and amygdaloid which are less water-worn than the sandstones and other foreign ingredients. The uppermost 2 or 3 feet of the intercalation consist of dark carbonaceous mudstone or shale, made up in large measure of volcanic detritus, which may have been derived partly from eruptions of fine dust, partly from subaerial disintegration of the basalt-sheets. Some layers of these finer strata are full of remains of much macerated plants.

Other thin coaly intercalations have been observed among the basalts of Canna, some of which may possibly mark still higher horizons than those now described. But, confining our attention to the regular sequence of intercalations exposed along the Sanday coast, we find at least four distinct platforms of interstratified sediment among the plateau-basalts of this district. Each of these marks a longer or shorter interval in the outflow of lava, and points to the action of moving water over the surface of the lava-fields.

We may now consider the probable conditions under which this intervention of aqueous action took place. The idea that the sea had anything to do with these conglomerates, sandstones, and shales may be summarily dismissed from consideration. The evidence that the basalt-eruptions took place on a terrestrial surface is entirely convincing, and geologists are now agreed upon this question.

Excluding marine action, we have to choose among forms of fresh water—between lakes on the one hand and rivers on the other. That the agency concerned in the transport and deposition of these strata was that of a river may be confidently concluded on the following grounds:—

1. The large size and rolled shapes of the boulders in the conglomerates. To move blocks several tons in weight, and not only to move them but to wear them into more or less rounded forms, must have required the operation of strong currents of water. The coarse detritus intercalated among the basalts is quite comparable to the shingle of a modern river, which descends with rapidity and in ample volume from a range of hills.

2. The evidence that the materials of the conglomerates are not entirely local, but include a marked proportion of foreign stones.

The proofs of transport are admirably exhibited by the pieces of Torridon Sandstone, epidotic grit, quartzite, and other hard rocks, none of which occur *in situ* except at some distance from Canna. These stones are often not merely rounded, but so well smoothed and polished as to show that they must have been rolled along for some considerable time in water.

3. The lenticular character and rapid lithological variations of the strata, both laterally and vertically. The coarse conglomerates die out as they are followed along their outcrop and pass into finer sediment. They seem to occur in irregular banks, which may not be more than 200 feet broad, like the shingle-banks of a river. The coarser sediment generally lies in the lower part of the sedimentary group. But cases may be observed, such as that shown in fig. 16, p. 361, where the fine sediment laid down upon the bottom conglomerate has subsequently been overspread by another inroad of coarse shingle. Such alternations are not difficult to understand, if they are looked upon as indicating the successive floods and quieter intervals of a river.

For these reasons I regard the platforms of sedimentary material intercalated among the basalts of Canna and Sanday as the successive flood-plains of a river which, like the rivers that traverse the lava-deserts of Iceland, flowed perhaps in many separate channels across the basalt-fields of the Inner Hebrides and was liable to have its course shifted from time to time by fresh volcanic eruptions. That this river came from the east or north-east and had its source among the western highlands of Inverness-shire may be inferred from the nature of the stones which it has carried for 30 miles or more along its bed. And that it crossed in its course the tract of Torridon Sandstone, of which a portion still remains in Rum, is manifest from the abundance of the fragments of that formation in the conglomerates.

With the remarkable exception of the section on Dùn Beag, to be immediately referred to, no trace of any eroded channel of this river through the lavas of the great volcanic plain has been preserved. Possibly frequent invasions of its bed by streams of basalt from different vents hindered it from remaining long enough in one course to erode anything like a gorge or cañon. But, in any case, the main channel of the river probably lay rather to the east of the present islands of Canna and Sanday, on ground which is now covered by the sea. The banks or sheets of boulder-conglomerate undoubtedly show where its current swept with great force over the lava-plain, but the manner in which these coarser materials are so often covered with fine silt suggests that the sedimentary materials now visible were deposited rather on the low grounds over which the stream rushed in times of flood. Pools of water would often be left after such inundations, and in these depressions silt would gradually accumulate, partly carried in suspension by the river, partly washed in by rain, while drift-wood that found its way into these eddies, and leaves blown into them from the trees and shrubs of the surrounding country, would remain for some time afloat, and would be the last of the detritus to sink to the bottom. Hence, no doubt,

the carbonaceous character of the hardened silt in the upper part of each intercalation of sediment.

If we were to look upon the volcanic materials in the conglomerates as derived from the subaerial disintegration of the fields of basalt, we should be compelled to admit a very large amount of erosion of the surface of the volcanic plain during the period when the river flowed over that tract. It would be necessary to suppose not only that there was a considerable rainfall, but that the differences of temperature, either from day to night or from summer to winter, were so great as to split up the lavas at the surface in order to provide the river with the blocks which it has rolled into rounded boulders. I do not think, however, that such a deduction would be sound. If we compare the materials that have filled up the eruptive vent at the eastern end of Canna with the great majority of the blocks in the coarse conglomerates, we cannot fail to note their strong resemblance. The abundance of lumps of slaggy lava in the river-shingle corresponds with their predominance in the agglomerate of the vent. The boulders of basalt, dolerite, and andesite which crowd the conglomerates need not have been derived from the action of atmospheric waste on the lava-fields, but might quite well have been mainly supplied by the demolition of one or more volcanic cones of fragmental materials.

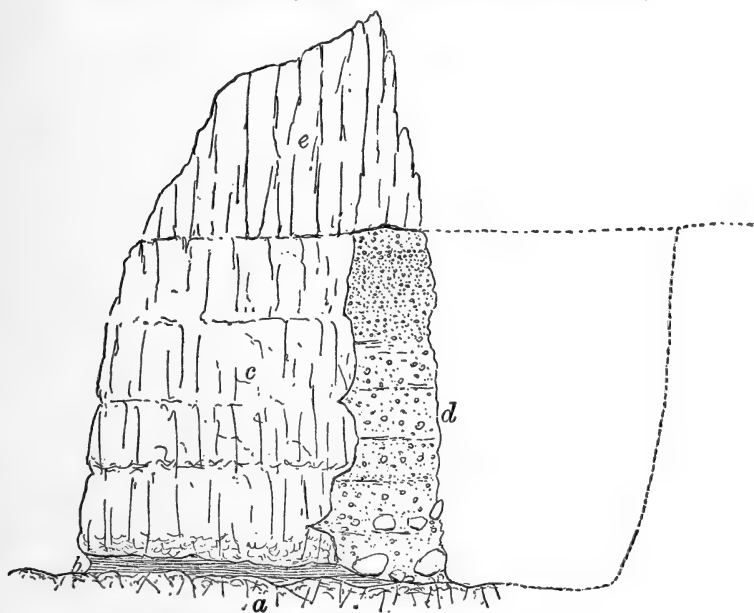
That such has really been the chief source of the blocks in the conglomerates I cannot doubt. At the eastern end of Canna we actually detect a volcanic cone partly washed down and overlain by a pile of river-shingle. There were probably many such mounds of slag and stones along lines of fissure all over the lava-fields. The river in its winding course might come upon one cone after another, and during times of flood, or when its waters burst through any temporary barrier created by volcanic operations it would attack the slopes of loose material and sweep their detritus onward. At the same time, the current would carry forward its own natural burden of far-transplanted sediment, and hence on its old flood-plains, buried and preserved under sheets of basalt, we find abundant pebbles of the old Highland rocks which it had borne across the whole breadth of the basaltic lowland.

But the destruction of volcanic cones was probably not the only source of the detritus that now forms the conglomerates of Canna and Sanday. I have shown that these conglomerates pass laterally into tuffs, and are sometimes underlain, sometimes overlain, with similar material. It is quite obvious that their deposition was contemporaneous with volcanic action in the immediate neighbourhood, and that at least part of their finer sediment was obtained directly from volcanic explosions. In wandering over the coast-sections of these remarkably coarse deposits, I have been impressed with the enormous size of many of the stones, their resemblance to the ejected blocks of the agglomerate and the distinction that may sometimes be made with more or less clearness between their rather angular forms and the more rounded and somewhat waterworn aspect of the other boulders. It seems to me not improbable that

some of the remarkably coarse masses of unstratified conglomerate in Canna Harbour consist largely of ejected blocks from the adjacent vent.

The only instance which I have observed of erosion of the basalts contemporaneous with the operations of the river that spread out this conglomerate is to be found in the striking stack of Dùn Beag already alluded to.<sup>1</sup> This extraordinary monument of geological history forms an outlying obelisk which rises from the platform of the shore to a height of about 70 feet. Seen from the south-west it appears to consist entirely of bedded basalt resting on some stratified tuff and shale which intervene between these lavas and that of the broad platform of basalt on which the obelisk stands.

Fig. 18.—Section of the eastern front of the Dùn Beag.



- a. Very slaggy amygdaloidal basalt.
- b. Shales and tuff.
- c. Slaggy and jointed basalts.

- d. Conglomerate.
- e. Prismatic basalt.

The dotted lines indicate the supposed form of the ravine.

On that side it presents no essential difference from the structure of the Dùn Mòr on the west, save that the lower conglomerate of that outlier is here represented by fine sediment, and the upper conglomerate is wanting. The general aspect of this south-western

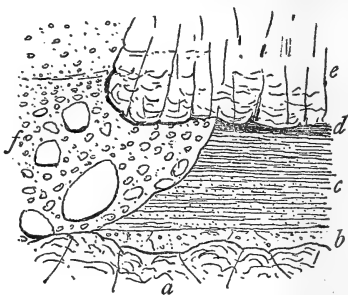
<sup>1</sup> This pinnacle of rock is referred to by Macculloch in his account of Canna, and is figured in pl. xix. fig. 3 in his work already cited. But neither his description nor his drawing conveys any idea of the real structure of the rock.

front of the stack is shown in Pl. XVIII. If, however, we approach the rock from the coast-gully to the north, we form a very different impression of its structure. It then appears to consist chiefly of conglomerates with a capping of basalt on the top. It is not until a close scrutiny is made of the eastern and western faces of the column that the true structure and history of this singular and striking piece of topography become apparent.

On the eastern front the section represented in fig. 18, p. 367, is exposed. At the bottom, forming the pediment of the column, lies a sheet of slaggy and vesicular or amygdaloidal basalt (*a*), which shelves gently in a south-westerly direction into the sea. The lowest band (*b*) in the structure of the stack is a thin group of lilac, brown, and green shale and volcanic mudstone or tuff, which encloses pieces of coniferous wood, and becomes markedly carbonaceous in its uppermost layers. Above these strata on the southern front comes the pile of bedded basalts (*c*) with their slaggy lower and upper surfaces. But as we follow them round the eastern side we find them abruptly cut off by a mass of conglomerate (*d*). That the vertical junction-line is not a fault is speedily ascertained. The lower platform of slaggy basalt runs on unbroken under both the shales and the conglomerate. Moreover, the line of meeting of this conglomerate with the basalts that overlie the shales is not a clean-cut straight wall, but displays projections and recesses of the igneous rocks round and into which the materials of the conglomerate have been deposited. The pebbles may be seen filling up little crevices, passing under overhanging ledges of the basalts, and sharply truncating lines of scoriaceous structure in these rocks. The same relations may be observed on the western front of the stack. There the ashy shales and tuffs are sharply cut out by the conglomerate which wraps round and underlies a projecting cornice of the slaggy bottom of the basalt that rests on the stratified band (fig. 19).

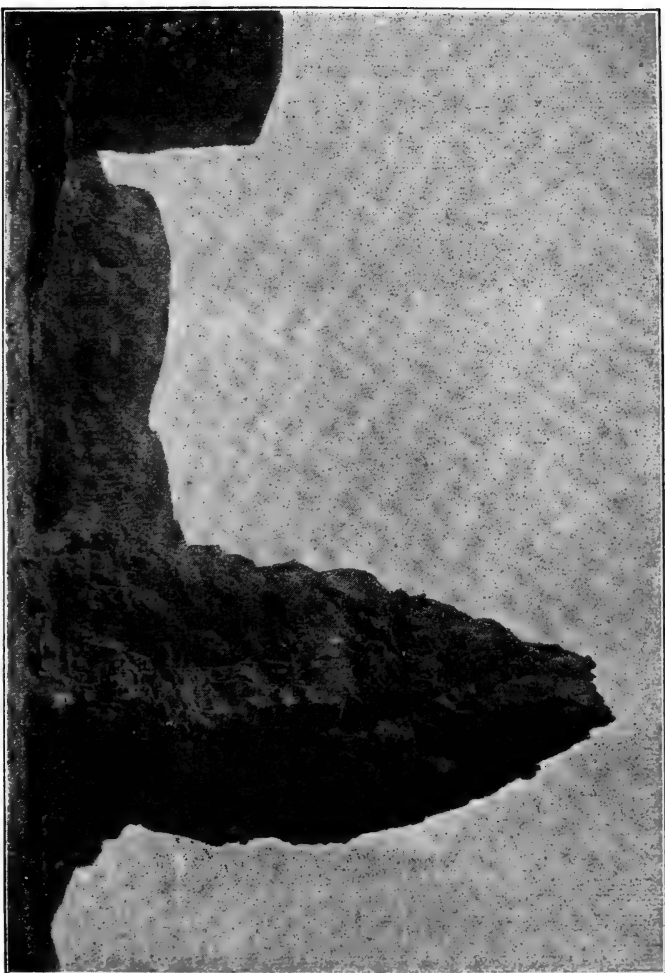
The conglomerate is rudely stratified horizontally, its bedding being best shown by occasional partings of greenish sandstone. It consists of well-rounded, polished, and water-worn stones, chiefly of members of the volcanic series,—basalts, and dolerites, both compact and amygdaloidal or slaggy,—but with a conspicuous admixture of Torridon Sandstone, gneiss, grey granite, grit, and different schists. The coarsest part of the deposit lies towards the bottom, where the volcanic blocks are sometimes 6 and 8 feet in diameter. Some of these large masses

Fig. 19.—*Enlarged section on the western side of the Dùn Beag.*

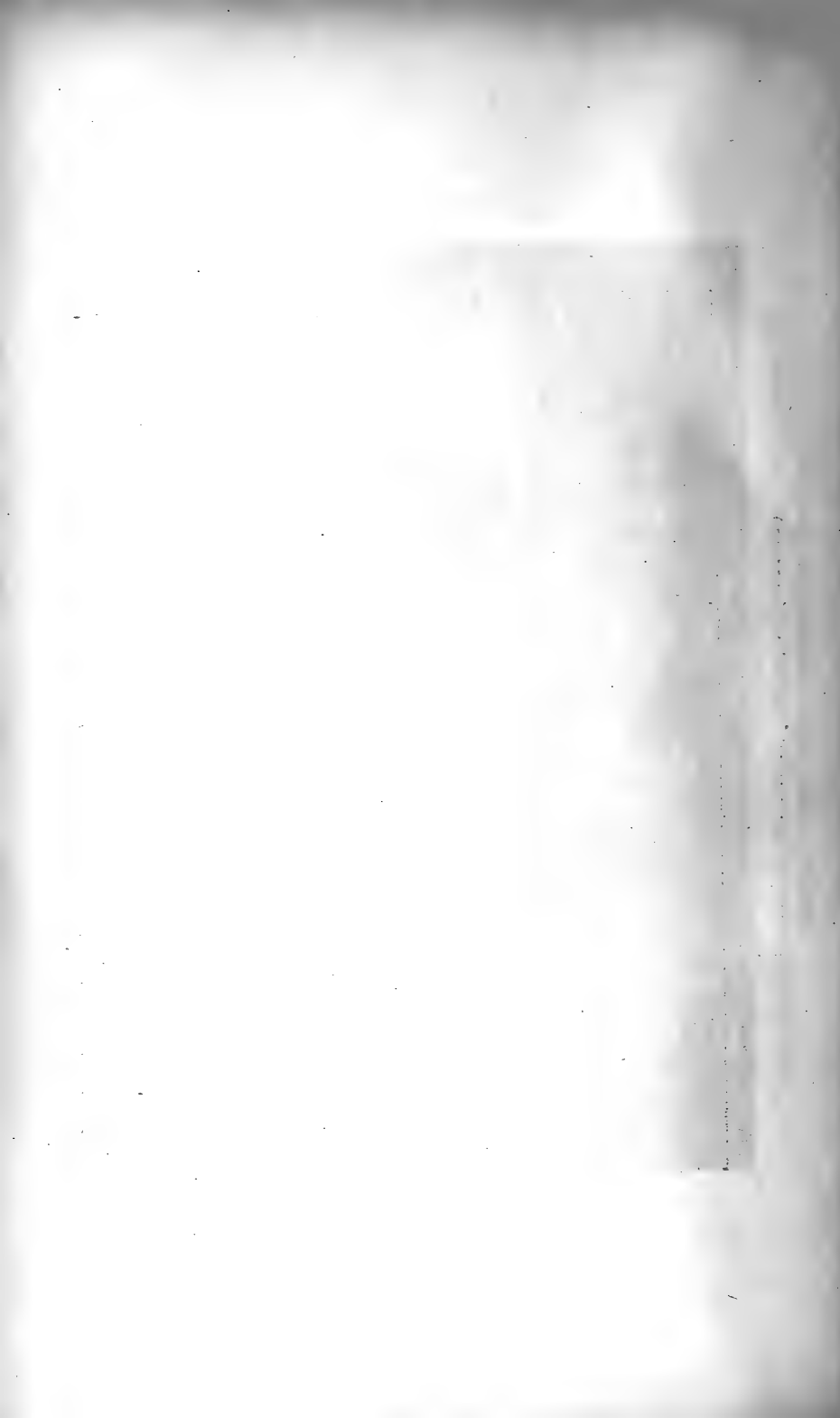


*a*, amygdaloid; *b*, tuff; *c*, ashy shales; *d*, layer of coaly shale; *e*, amygdaloidal basalts; *f*, conglomerate.





DÙN BEAG, SANDAY, SEEN FROM THE SOUTH-WEST.  
(From a photograph by Miss THOM, of Canna.)





DUN BEAG, SANDAY, SEEN FROM THE NORTH. THE ISLAND OF RUM IN THE DISTANCE.  
(From a photograph by Miss Thom, of Canna.)



may have originally fallen from the basalts against which the conglomerate now reposes. The far-transported stones are also of considerable size, pieces of granite and gneiss frequently exceeding a foot in length. The well-rounded pebbles of foreign materials have been washed into the interstices between the large volcanic blocks.

It is, I think, tolerably clear that the wall of basalt against which this conglomerate has been laid down is one of erosion. The beds of basalt have here been trenched by some agent which has likewise scooped out the soft underlying shales, and even cut them away from under their protecting cover of basalt, as shown in figs. 18 & 19. There can be little hesitation in regarding this agent as a water-course which for some considerable interval of time continued to dig its channel through the hard basalts. There is not room enough between the basalt-wall of the Dùn Beag and the opposite cliffs of the shore (where no trace of this conglomerate is to be seen) for any large stream to have found its way. I do not, therefore, seek to identify this relic of an ancient waterway with the channel of the main river which deposited the conglomerate-bands of Canna and Sanday. More probably it was either a mere torrential chasm or a tributary stream, draining a certain part of the volcanic plateau and allowed to retain its channel long enough to be able to erode it to a depth of nearly 50 feet. Erosion had reached down through the underlying tuffs to the slaggy basalt below, but before it had made any progress in that sheet its operations were brought to an end at this locality by the floods that swept in the coarse shingle and by the subsequent stream of basalt, of which a mere outlying fragment now forms the upper third of the stack (*e* in fig. 18).

The ravine or gully of the Dùn Beag probably lay within reach of the floods of the main river, as may be inferred from the number and size of the far-transported rocks in its conglomerate. The conditions of deposition remained little changed during the process of filling up with detritus, except that the largest blocks of rock were swept into the chasm in the earlier part of its history, while much smaller and more waterworn shingle was introduced towards the close.

Denudation, which has performed such marvels in the topography of the West of Scotland since older Tertiary time, has here obliterated every trace of this ancient gully, save the little fragment of one of the walls which survives in the stack of Dùn Beag. When in the course of centuries this picturesque obelisk shall have yielded to the action of the elements, the last leaflet of one of the most interesting chapters in the geological history of the Inner Hebrides will have been destroyed.

The question naturally arises, What was the subsequent history of the river which has left so many records of its floods entombed among the basalts of Canna and Sanday? In particular, can any connexion be traced or plausibly conjectured between it and the river-bed preserved under the Scur of Eigg?

In dealing with this subject, though the evidence is admittedly

scanty, we are not left wholly to conjecture. A consideration of the general topographical features of the wide region of the Inner Hebrides, from the beginning of the volcanic period onward, will convince us that, in spite of the effects of prolonged basalt-eruptions, the persistent flow of the drainage of the Western Highlands must have taken a westerly direction. It was towards the west that the low grounds lay. Though the long and broad valley which stretched northwards from Antrim between the line of the Outer Hebrides and the West of Scotland was gradually buried under a depth of 2000 or 3000 feet of lava, the volcanic plain that overspread it probably remained even to the end lower than the mountainous Western Highlands. Hence the rivers, no matter how constantly they may have had their beds filled up and may have been driven into new channels, would nevertheless always seek their way westward into the Atlantic.

On Canna and Sanday we have the traces of a river which poured its flood-waters across the lava-fields in that part of the volcanic region, while the basalts were still from time to time streaming from vents and fissures. Not more than 14 miles south-east stands the Scur of Eigg, with its buried river-channel and its striking evidence that this river likewise flowed westward, though at a far later time, when the basalt-eruptions had ceased and the volcanic plain had been already deeply trenched by erosion, but when the subterranean fires were not yet quenched.

When one reflects upon the enormous denudation of this region, to which further reference will be made in the sequel, one is not surprised that many connecting-links should have been effaced. The astonishment rather arises that so continuous a story can still be deciphered. Even, however, had the original record been left complete, it would have been exceedingly difficult to trace the successive mutations of a river-channel during long ages of volcanic eruptions. Such a channel would have been concealed from view by each lava-stream that poured into it, and would not have been again exposed save by the very process of erosion that destroys while it reveals.

While, therefore, there is not and can never be any positive proof that in the fluvial records of Canna, Sanday, and Eigg successive phases are registered in the history of one single stream, I believe that this identity is highly probable. It was a river which rose among the mountains of Western Inverness-shire, and had already taken its course to the sea before any volcanic eruptions had begun. It continued to flow westward across the lava-floor that gradually spread over the plains. Its channel was constantly being filled up by fresh streams of basalt, or deflected by the uprise of new cinder-cones. But, fed by the Atlantic rains, it maintained its seaward flow until the general subsidence which carried so much of the volcanic plain below the sea. Yet the higher part of this ancient watercourse is no doubt unsubmerged, still traversing the schists of the Western Highlands as it has done since older Tertiary time. It may, perhaps, be recognized in one of the glens which

carry seaward the drainage of the districts of Morar, Arisaig, or Moidart.

When one scans the great precipice on the western side of the island of Eigg, which displays a transverse section across the pitchstone-lava with its buried river-bed and the basalt-plateau underneath, there seems no chance of any further westward trace of this pitchstone being ever found. The truncated end of the Scuir looks from the top of the cliff out to sea, and the progress of denudation might have been supposed to have effectually destroyed all evidence of the continuation of the rock in a westerly direction. Some years ago, however, my friend Prof. Heddle, while cruising among the Inner Hebrides, landed upon the little uninhabited islet of Hysgeir, which rises out of the open sea, some 18 miles to the westward of Eigg. He at once recognized the identity of the rock composing this islet with that of the Scuir, and in the year 1892 published a brief account of this interesting discovery.<sup>1</sup>

I have myself been able to land on Hysgeir in two successive summers, and can entirely confirm Prof. Heddle's identification. The islet stands on the eastern edge of the submarine ridge which, running in a north-easterly direction, culminates in the island of Canna. Hysgeir is a mere reef or skerry, of which the top rises only 38 feet above the Ordnance datum-level. Its surface is one of bare rock, save where a short but luxuriant growth of grasses has found root on the higher parts of two or three of its ridges, and on the old storm-beach of shingle which remains on the summit. The rock undulates in long low swells that run in a general direction 20° to 45° west of north, and are separated by narrow channels or hollows. The place is a favourite haunt of gulls, terns, eider-ducks, and grey seals, and is used by the proprietor of Canna for the occasional pasturage of sheep or cattle. So numerous are the sea-fowl during the breeding-season that the geologist, intent upon his own pursuits, may often tread unawares on their nests, while he is the centre of a restless circle of white wings and anxious cries.

The pitchstone of Hysgeir, like that of Eigg, is columnar, the columns being irregularly polygonal and varying from 3 to 10 inches in diameter. They are packed so close together that the domes of rock on which their ends appear look like rounded masses of honeycomb. They may here and there be observed to be arranged radially, with their ends at right angles to the curved exterior of the ridges, as if this external surface represented the original form of the cooled pitchstone, and were not due to mere denudation. There can be no doubt, however, that the island has been well ice-worn.

At the north-western promontory a beautiful example of fan-shaped grouping of columns may be observed on a face of rock which descends vertically into the sea. Here, too, is almost the only section on which the sides of the columns may be examined, for, as

<sup>1</sup> Appendix C to 'A Vertebrate Fauna of Argyre and the Inner Hebrides,' by J. A. Harvie-Brown and Thomas E. Buckley, p. 248.

a rule, it is merely their ends on the rounded domes which are to be observed, and which everywhere slip under the waves. The columns in a cliff from 15 to 20 feet high show the slightly wavy, starch-like arrangement so often to be met with among the plateau-basalts.

The rock presents a tolerably uniform texture throughout, though in some parts it is blacker, more resinous, and less charged with porphyritic enclosures than in the general body of the rock. Large fresh feldspars are generally scattered through it. To the naked eye it reproduces every feature of the pitchstone of the Scur of Eigg.

A microscopic examination completes our recognition of the identity of these two rocks. Mr. Harker has examined a thin slice prepared from the Hysgeir pitchstone, and remarks regarding it that 'the large feldspars are not the only porphyritic element. The microscope shows the presence also of smaller imperfect crystals of augite, very faint green in the slice, and small grains of magnetite. The feldspars have been deeply corroded by the enveloping magma, and irregular included patches of the groundmass occupy nearly half the bulk of some of the crystals. This latter feature is seen especially in some of the larger crystals, which seem to be sanidine. They are, for the most part, apparently simple crystals, but in places there is a scarcely defined lamellar twinning, or, again, small patches not extinguishing with the rest; so that we are probably dealing with some perthitic intergrowth on a minute scale.'<sup>1</sup>

'Rather smaller feldspar-crystals are rounded by corrosion, but lack the inclusions of groundmass; these have albite- and sometimes pericline-lamellation, and may be referred to oligoclase-andesine. The groundmass of the rock is a brown glass with perlitic cracks, enclosing very numerous microlites of feldspar about .001 inch in length [6619]. The rock is probably to be regarded as a dacite rather than a rhyolite, and thus agrees with Mr. Barker-North's analysis of the Eigg pitchstone.'<sup>2</sup> There is no trace of any conglomerate *in situ* like that under the Scur of Eigg, nor of any other rock, aqueous or igneous. As the pitchstone everywhere slips under the sea, its geological relations are entirely concealed.

The great variety of materials met with in the form of boulders on Hysgeir is a testimony to the transport of erratics from the neighbouring islands and the mainland during the Glacial Period. The most abundant rock in these boulders is Torridon Sandstone, derived, no doubt, from the hills of Rum; but there occur also various kinds of schist, gneisses, quartzites, granites, porphyries, probably from the west of Inverness-shire, as well as pieces of white sandstone, probably Jurassic, which may have come from Eigg.

That the pitchstone of Hysgeir is a continuation of that of the Scur may be regarded as highly probable. If not a continuation, it must be another stream of the same kind, and doubtless of the same date. If it be regarded as probably a westward prolongation of

<sup>1</sup> Comp. Prof. Judd's remarks on the Scur of Eigg rock, *Quart. Journ. Geol. Soc.* vol. xlvi. (1890) p. 380.

<sup>2</sup> *Ibid.* p. 379.



the Eigg rock, and if it is about as thick as that mass at the western end of the Scur, then its bottom lies 200 or 300 feet under the waves. The river-channel occupied by the Eigg pitchstone undoubtedly sloped from east to west. The position of Hysgeir, 18 miles farther west, indicates a further fall in the same direction at the rate of perhaps as much as 35 feet in the mile.<sup>1</sup> Unfortunately, however, as no trace of the river-bed can now be seen on this island, any statement in regard to its prolongation must rest on mere conjecture.

#### IV. THE BASIC SILLS.

One of the most characteristic structural features in the basalt-plateaux of North-western Europe is the number, thickness, and extent of the basic sills or intrusive sheets which accompany these piles of volcanic material. As I have formerly shown,<sup>2</sup> the sills, though they may be observed in any part of the basalt series, are more particularly developed at its base, and are notably interpolated among the Secondary formations which underlie it. In addition to the examples which I have already described, the following localities are here cited as affording excellent illustrations of the more characteristic features of intrusive sheets.

The eastern coast of Skye has been classic ground for this part of volcanic geology since the publication of Macculloch's descriptions and diagrams. From the mouth of Loch Sligachan to Rudha Hunish, at the northern end of the island, a series of sills may be traced, sometimes crowning the cliffs as a columnar mural escarpment, sometimes burrowing in endless veins and threads through the Jurassic rocks. The horizontal distance to which this band of sills extends in Skye is not far short of 30 miles. But it stretches beyond the limits of this island. It forms the group of islets which prolong the geological structure and topographical features of Trotternish for 4 miles farther to the north-west. It reappears 10 miles still farther on in the Shiant Isles. Since its total visible length is fully 40 miles. As a display of intrusive basic igneous rocks it ranks next to the Great Whin Sill among the British instances of this tectonic type.

The larger sheets in this belt have certain characteristic features. They are generally somewhat coarsely crystalline ophitic dolerites or diabases, and exhibit the persistent uniformity of composition and structure so characteristic of intrusive sheets and dykes. They display in many cases a regularly prismatic arrangement, the columns being much thicker and longer than those of the basalts of the plateaux or those of the dykes and veins. The regularity of this structure is well shown in the great sill of which the Kilt Rock is one of the most noted portions (fig. 20, p. 374). But the most astonishing example is that which forms the Garbh Eilean of the Shiant Isles, where the sill presents to the sea a vertical columnar

<sup>1</sup> Rep. Brit. Assoc. 1894 (Oxford meeting), p. 653.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 296; Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 111.

Fig. 20.—*Columnar sill intrusive in Jurassic strata east of Kilmartin, Trotternish, Skye.*

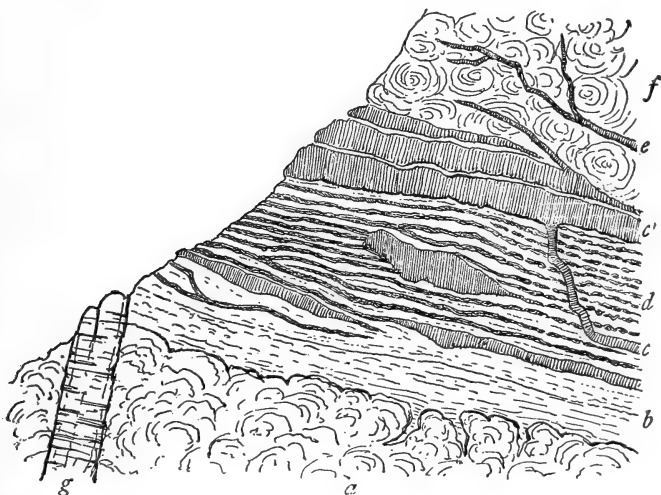


[The high ground on the left is a portion of the basalt-plateau to the north of the well-known Quiraing.]

wall 500 feet high. Though I could not certainly trace any single column continuously from bottom to top of the precipice, many of them must be at least 300 or 400 feet long. No other sill in the British Islands forms such a noble escarpment as this.

In contrast to such enormous thicknesses of intrusive material, instances may be culled from the same belt of sills where the molten rock has been injected in thin cakes and mere threads into the Jurassic sandstones and shales, or into the shales and coals intercalated among the plateau-basalts. Thus, on the cliff immediately north of Ach na Hannait, between Loch Sligachan and Portree Bay, the section which is represented in fig. 21 may be seen.

Fig. 21.—Section of thin intrusive sheets and veins in carbonaceous shales lying among the plateau-basalts. Cliff north of Ach na Hannait, between Portree Bay and Loch Sligachan.



At the base lies a vesicular dolerite with a slaggy upper surface (*a*). Next comes a zone of sedimentary material about 5 or 6 feet thick, the lower portion consisting of an impure coal, which passes towards the right hand into brown and grey carbonaceous shale with plant-remains (*b*). This coaly layer has been already alluded to as probably lying on the same horizon with the coal of Portree. Traced northward, it is found to have a bed of fine tuff beneath it, and sometimes a volcanic breccia or conglomerate. It fills up rents in the underlying slaggy lava, and was undoubtedly deposited upon the cooled surface of that rock. Immediately above this lower band the black carbonaceous shale (*d*) which follows has been invaded by an extraordinary number of thin cakes or sills, and also by veins or threads of basalt. For a thickness of 2 or 3 feet the band consists mainly of these intrusions, which, in the form of a fine

grey basalt, vary from less than 1 to 3 or 4 inches in thickness. They are separated by thin partings of coaly shale, and as they tend to break up into detached nodule-like portions, especially towards the right hand of the section represented in fig. 21, they might, on casual inspection, be easily mistaken for nodules in the dark shales. Somewhat later in the time of intrusion are veins of basalt which, as at *c*, break across the nodular sills, and sometimes expand into thicker beds (*c'*).

I have never seen such a congeries of minute sills among the Tertiary basalt-plateaux as that here exhibited. In a space of about 3 feet of vertical height there must be more than a dozen roughly parallel cakes of intrusive rock. Veins (*e*) run up from the chief band of eruptive material into the overlying finely vesicular basalt (*f*). The dyke (*g*) is probably the youngest rock in the section.

The amount of contact-metamorphism effected even by such thick sills as those of Trotternish and Shiant is much less than might be expected. It seldom goes beyond a mere induration of the strata for a few yards, often only for a few inches from the surface of junction. In the Shiant Isles the shales on which the sills rest have undergone a remarkable alteration. They have been greatly indurated, and have acquired a globular or botryoidal structure. The spheroidal aggregates vary from not more than a line to more than half an inch in diameter, and appear on the surface as dark, irregularly grouped, pea-like aggregates. This structure is perhaps best developed immediately under the thick sill that forms Eilean Muirhi.<sup>1</sup>

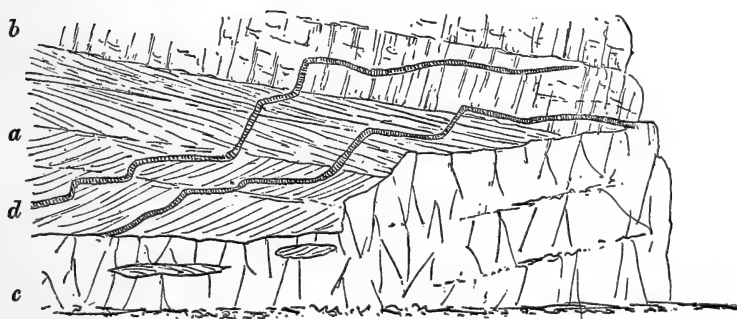
On the western side of Skye, owing to greater local subsidence of the basaltic plateau, the base of the volcanic series is seldom seen, and hence the platform of sills is for the most part concealed under the sea. But where at one or two points the Jurassic strata are brought up to the light of day, they have carried with them their intrusive sheets of basic rock. Thus, at the mouth of Dunvegan Loch, the islets of Mingay and Clett form parts of a sill which rests on shell-limestones full of oysters (*Ostrea hebridica*), referable to the Loch Staffin group of the Great Oolite Series. This rock, when observed from a little distance, presents the usual regularly prismatic or columnar structure so well developed among the Trotternish sills, but on a closer view shows this structure much less distinctly. It is an olivine-dolerite of medium and fine texture, which in thin slices displays under the microscope a distinctly ophitic structure, the abundant light-brown augite enclosing the striated feldspars. Its lowest portion, from 3 to 7 or 8 inches upward from the bottom, is much closer-textured than the rest of the rock and is finely amygdaloidal. Its vesicles are in many cases drawn out to a length of 3 or 4 inches, and the zeolites which now fill them look like parallel annelid tubes or stems of *Lithostrotion*. It is noteworthy also that the elongation of the vesicles has

<sup>1</sup> Macculloch, 'Description of the Western Islands,' vol. i. (1819) p. 441.

sometimes taken place at right angles to the surface of contact with the underlying strata. But the most remarkable feature in this sill is the surface which it presents to the oyster-beds on which it rests. The fine-grained dark dolerite has there assumed the aspect of a sheet of iron-slag, with a smooth or wrinkled, twisted, ropy surface, which displays fine curving flow-lines. No one looking at a detached specimen of this surface would be ready to admit that it could possibly have come from anything but a true lava-stream that flowed out at the surface. The contours of a viscous lava are here precisely reproduced on the under surface of a massive sill.

A little farther south the promontory of Eist, which forms the western breakwater of Moonen Bay, is formed by another important sill or group of sills which has insinuated itself among shales, shell-limestones, and shaly sandstones, full of *Ostrea hebridica*, *Cyrena aurata*, etc., and belonging to the Loch Staffin group of the Great Oolite Series. The shore-cliff below the waterfall affords the section given in fig. 22, illustrating the manner in which a thick intrusive sheet may sometimes give off thin veins from its mass. The rock attains on the Eist promontory a thickness of

Fig. 22.—Upper part of sill in Moonen Bay, Waternish, Skye, showing the divergence of veins.



a. False-bedded shaly sandstone; b. Shell-limestone (Great Oolite Series); c. Dolerite-sill; dd. Veins proceeding from the sill. Length of section = about 5 yards.

probably at least 100 feet, where it is thickest and undivided. But the two main sheets, or branches of one great sheet, on this peninsula have probably an united depth of more than 300 feet. Landwards the rock splits up and encloses cakes of the Jurassic strata. It possesses the usual prismatic structure and doleritic composition. In Moonen Bay, as shown in fig. 22, it presents a banded structure, marked especially by alternation of lines of amygdulæ and layers of more compact and solid dolerite, with occasional enclosed cakes of baked shale or sandstone. Its upper surface is somewhat uneven, and from it are given off narrow, wavy, ribbon-like veins (d), from

less than 1 to 3 inches or more in width, which keep in a general sense parallel to the top of the sill, but at a distance of a few inches or feet from it. The sill becomes as usual fine-grained towards the contact, the shales and sandstones being indurated and the limestone marmorized.

Still farther south the bottom of the basalt-plateau is again reached in the Sound of Soa, where the volcanic pile has been poured out over the upturned edges of the Torridon Sandstone. It is hardly possible to exaggerate the wild confusion of sills, dykes, and veins which have been injected among the rocks at and on both sides of the unconformability. Endless sheets of basalt and dolerite have forced their way between the bedded basalts and the sandstones, while across the whole rise vast numbers of dykes and veins. Narrow, black, wavy ribbons of basic material cross many of these veins, while the later north-western dykes cut sharply through everything older than themselves. As a natural section for the study of the phenomena of intrusion in many of their most characteristic phases, I know no locality equal to the northern coast-line of the Sound of Soa, unless it be the cliffs of Ardnamurchan. But the Skye cliffs, though less imposing than those of the great Argyre-shire headland, have this great advantage, that instead of being exposed to the full roll of the open Atlantic, they form the margin of a comparatively sheltered strait, and can thus be conveniently examined.

There is one remaining locality in Skye to which I wish to direct attention, since it displays certain phenomena of sills which I have never seen so perfectly exhibited elsewhere. It lies on the western side of the promontory of Sleat, about midway between the basalt-plateau of Strathaird and that of Eigg, and about 8 or 9 miles in a direct line from either. The basalts cannot be proved to have once stretched continuously between Eigg and Strathaird, and to have covered this part of Sleat; but the position of the rocks which I am about to describe makes it probable that this continuation did formerly exist. The denudation of the West of Scotland since early Tertiary time has been so stupendous that I am prepared for almost any seemingly incredible evidence of its effects. There cannot be any doubt, however, that the rocks of which I now speak belong to the great platform of intrusive sheets, and that they were injected under a pile of Secondary strata, if not also of Tertiary basalts, which has here been entirely removed.

In his map of Skye Macculloch showed a small outlier of 'trap' on the western side of the promontory of Sleat. The locality was visited by Prof. Judd, who called the rock a 'phonolite.'<sup>1</sup> During an excursion last year with my colleague Mr. C. T. Clough, I was able to examine the place and to obtain the facts which I now describe.

At Rudh' an Iasgaich, about 2 miles from the Point of Sleat, a small outlier of conglomerate lies on the edges of the Torridon

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 692.

Sandstone. This deposit has been correctly identified by Prof. Judd with the similar strata which in Skye and elsewhere on the west coast of Scotland underlie the Liassic series. It is here about 10 or 12 feet thick, reddish and yellowish in colour, and distinctly calcareous. Its component pebbles consist largely of Cambrian (Durness) limestone, quartzite, and Torridon Sandstone—rocks which all occur *in situ* in Sleat. It may be compared with the limestone-conglomerates of Strath, and those which underlie the Lias at Heast on Loch Eishort.<sup>1</sup> That here, as elsewhere in this region, the basement-conglomerate was followed by the rest of the Lias and Oolites may be inferred with some confidence from the copious development of the Jurassic Series a few miles off, both to north and south. But the whole of this overlying succession of formations has here been swept away, and, but for the protection afforded by the eruptive rocks of Rudh' an Iasgaich, the conglomerate would likewise have disappeared.

Above the conglomeratic band lies a sheet of intrusive rock, which in one place has apparently cut it out, so as to rest directly upon the Torridon Sandstone (*a* in fig. 23, p. 380). The decay of the softer detrital rock underneath has caused the sill to break off in slices, which have left behind them a bold mural escarpment.

The rock of this sill (*b b*) is a rather coarsely-crystalline porphyritic olivine-dolerite, which towards the north attains a thickness of about 70 feet. It exhibits the usual prismatic jointing, though less perfectly than some of the Trotternish sills already referred to. Besides these vertical joints, it is also traversed by a system of horizontal divisional planes which, though somewhat irregular in their course, run, in a general sense, parallel to the upper and under surfaces of the sill.

It seems to have been along this transverse series of joints that a second sill (*c*), 5 or 6 feet thick, has been injected. The material of this younger intrusion is a black, finely crystalline dolerite or basalt, with rudely prismatic jointing. Its most striking feature, besides its regularity of position and persistency for several hundred yards as a platform along the shore, is the basalt-glass which marks both its under and upper surfaces of contact, and which is here developed upon a scale the equal of which I have not met with among the Tertiary sills of this country.

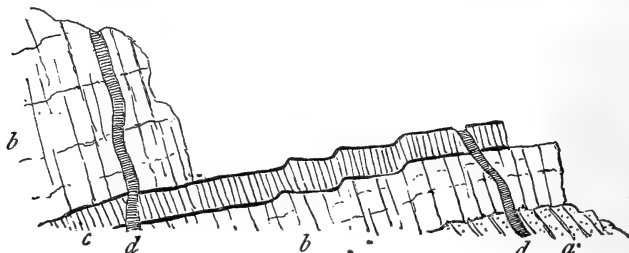
The selvage of glass appears as a black tar-like layer, varying from a mere film to 2 or 3 inches in thickness. It is found not only on the upper and under surfaces, but descends along abrupt step-like interruptions of the upper surface, a foot or more in height, as if the sill had been broken by a series of subsidences. The apparent fracture, however, is probably due to the irregularities of the passage forced for itself by the molten rock, as it passed from one line of horizontal joint to another through the heart of the older sheet.

The exposed surface of black glass on the top of the younger sill

<sup>1</sup> *Op. cit.* vol. xiv. (1858) p. 9; vol. xlv. (1888) p. 71.

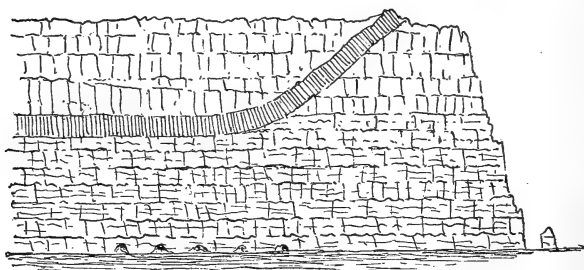
exhibits long parallel lines, probably marking flow-structure, which are made conspicuous by a pale yellow, ferruginous, weathered crust. Portions of the larger intrusive sheet have been broken off and involved in the later rock. The observer cannot fail to be impressed by the prodigious force with which the sills were injected, when he sees here that a thick sheet of solid dolerite has been actually

Fig. 23.—Section of dolerite-sill cut by another sill, both being traversed by dykes, Rudh' an Iasgaich, western side of Sleat, Skye.



split open along the middle. The younger sill disappears to the north, and is not found in the cliff of Rudha Chàrn nan Cearc, where the thick sill, lying once more on the band of conglomerate, forms a fine escarpment above the shore. Dykes of fine-grained basalt with compact chilled margins rise through both sills, together with veins which pursue a wavy upward path like strips of black ribbon.

Fig. 24.—Sill traversing bedded basalts, cliffs of Stromö, at the entrance of the Vaagöfjord.



[The caves and notches shown at the bottom of the precipice mark the position of the vents represented in Pl. XV. and figs. 8, 9, & 10.]

In the Faroe Islands the actual base of the volcanic series is nowhere visible. Hence, the great lower platform of intrusive sheets being there concealed, this feature of the basalt-plateaux is less conspicuous than it is in the Inner Hebrides. A number of



sills, however, have been noticed by previous observers,<sup>1</sup> and I have seen others on the sides of Stromö, Kalsö, Kunö, and other islands.

The most remarkable sill in the Faroe Islands is probably that which forms so prominent an object on the western cliffs of Stromö, at the entrance into the Vaagöfjord (figs. 24, 25). It is prismatic in structure, and where it runs along the face of the cliffs, parallel to the bedded basalts among which it has been intruded, presents the familiar characters of such sheets. It runs along the face of the precipice which rises above the row of volcanic vents already described. But it there begins to ascend the cliffs obliquely across the basalts, until it reaches the crest of the great wall of volcanic rock at a height of probably about 1000 feet above the waves. From the crest of the precipice the upward course of this sill is continued into the interior of the island. It pursues its way as a line of bold crag along the ridges of the plateau, gradually ascending till it forms the summit of one of the most prominent hills in the district.

Some further idea of the enormous energy with which the sills were injected may be formed from this example, where the eruptive materials followed neither the line of bedding nor a vertical fissure, but took an oblique course through the plateau-basalts for a vertical distance of probably more than 1500 feet.

In Skye a series of remarkable compound sills occurs where a central sheet of acid rock is overlain and underlain by a layer of basic material. I have already described some examples of this structure, and will cite some others in a later part of this paper.

<sup>1</sup> See in particular the description by Trevelyan and Allan, and references by Prof. James Geikie and Mr. Lomas already cited.



Fig. 25.—View of the same sill, seen from the channel opposite the island of Koller.

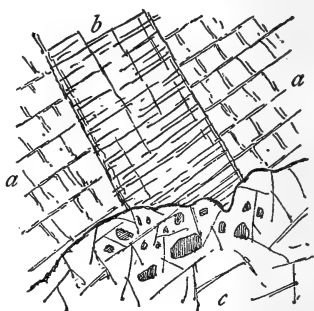
## V. THE DYKES.

I have little to add to the full description already given by me of the system of dykes which forms so important a feature in the volcanic history of Tertiary time throughout the North-west of Europe. It is difficult to establish any criterion of the relative dates of protrusion of the dykes; but the important fact announced by me so far back as 1857, that some are older and some later than the great acid bosses of the Inner Hebrides, has been fully confirmed by more recent research all over the region. So far as may be inferred from the geology of the Red Hills of Skye and their surroundings, the vast majority of the dykes belong to a time anterior to the uprise of the bosses of granophyre. As an example of the way in which these bosses truncate the dykes, I may cite here a fresh illustration from the granophyre of Ben an Dubhaich, near Torrin in Skye. The Cambrian limestones of that part of Strath are traversed by numerous dykes which stop short at the edge of the acid rock. As the actual lines of junction are not always visible, it might be contended that the dykes are not necessarily older than the granophyre, but may actually be younger, their sudden termination at the edge of the acid boss being due to their inability to traverse that rock. That this explanation is untenable is readily proved by such sections as that given in fig. 26, where a basic dyke 9 or 10 feet broad running through the Cambrian limestone of Torrin is abruptly cut off by the edge of the great granophyre boss of Ben an Dubhaich. Not only is the dyke sharply truncated, but numerous pieces of it, from 1 to more than 12 inches in length, are enclosed in the granophyre.

Mr. Harker informs me that, while carrying on the Geological Survey of the district of Strath (Skye), he has obtained data from which it may be possible to determine certain broad distinctions between dykes older and those newer than the intrusion of the granophyres. If these distinctions are found to hold good, they may eventually be applicable to the elucidation of the relative ages of dykes even at a distance from the granophyre, where nothing but petrographical characters are available as a guide.

Numerous basic dykes traverse the gabbros and granophyre of St. Kilda. Those in the former group of rocks are more abundant than those in the latter—a circumstance which is exactly paralleled among the basic and acid bosses of Skye. It is not improbable

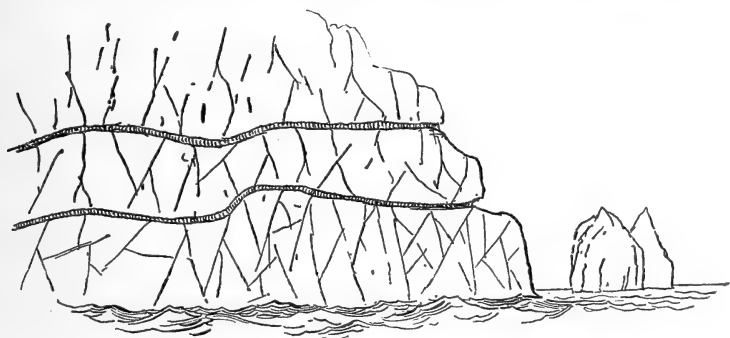
Fig. 26.—Ground-plan of basic dyke (b) in Cambrian limestone (a) truncated by granophyre (c) which encloses large blocks of the dyke. Torrin, Skye.



that in this remote island a similar difference in age and in petrographical character may be made out between two series of dykes, one older and the other younger than the granophyre.

The pale colour of the precipices in which the St. Kilda granophyre plunges into the sea gives marked prominence to the dark ribbon-like streaks which mark the course of the basalt-dykes through that rock. Moreover, the greater liability of the material of the dykes to decay causes them to weather into long lines of notch or recess. Four or five such dykes follow each other in nearly parallel bands, which slant upward from the sea-level on the eastern face of the hill known as Conacher to a height of several hundred feet (fig. 27).<sup>1</sup>

Fig. 27.—*Basalt-veins traversing granophyre. St. Kilda.*



Dykes abound in the Faroe Islands, where they cut the basalt-plateau in the same way as they do that of the Inner Hebrides. On the whole, however, they do not play, in these northern isles, the important part which they take in the geology and scenery of the West of Scotland. I have not had sufficient opportunity to ascertain whether there is a general direction or system among the Faroe dykes. In the fjords north of Thorshaven, and again along the western side of Stromö, many of them show an east-and-west strike or one from E.N.E. to W.S.W.

Numerous examples of compound dykes, where a central band of granophyre or spherulitic felsite is flanked on each side by one of basic material, have recently been met with in Skye by Messrs. Clough and Harker in the course of the geological survey of that island. They will be further noticed in the VIIth section of this paper.

<sup>1</sup> This relation of the later dykes to the granophyre was observed here by Macculloch, 'Description of the Western Islands,' vol. ii. (1819) p. 55.

## VI. THE INTRUSIVE GABBROS.

Some of my more recent observations among the gabbros of Skye have already been communicated to the Society.<sup>1</sup> In conjunction with my colleague Mr. Teall I have described a remarkable banded structure traceable in these rocks, wherein the component minerals have crystallized along different layers in such a manner as to present a singular resemblance to the arrangement characteristic of many Archæan gneisses. Further investigation last summer has shown me that this banding is extensively developed in the Cuillin Hills. The mountains that surround the head of Loch Scavaig and sweep round Loch Coruisk up to the great crests of Sgùrr na Banachdich everywhere display on their bare black crags a distinct bedded structure.

On the eastern side of Loch Scavaig the rock presents a rudely-banded character, the bands or beds being piled over each other from the sea-level up to the summits of the rugged precipices, and dipping into the hill at angles of 25° to 35°. Abundant dykes and veins of various basic, intermediate, and acid rocks cut this structure. The individual layers here, as at Druim an Eidhne,<sup>2</sup> are sometimes wavy and puckered.

Even from a distance the alternating lighter and darker beds can readily be seen, so that the banded structure, with the variations in its inclination, may be followed from hill to hill. The regularity of the arrangement, however, is often less pronounced on closer inspection. While the gabbro is rudely disposed in thick beds, indicative of different intrusive sheets or sills, with which the banding is generally parallel, considerable irregularities may be observed in the arrangement of the structure of individual sheets. These sheets may be parallel to each other, and yet, while in some the banding is tolerably regular in the direction of the planes of the sheets, in others it is much twisted or inclined at various angles.

On the western side of the Coruisk river the banding is vertical; southward from that stream it inclines slightly towards the south, but soon again becomes vertical, and continues conspicuously so at the junction of the gabbro with the Torridon Sandstones and the plateau-basalts on the western side of Loch Scavaig.

In the great corries and ridges of the Cuillin Hills traces of bedding are generally to be recognized, with later sills injected at different horizons and in different directions. Instead of being one great eruptive boss, the gabbro of this district is in reality an exceedingly complicated network of sills, veins, and dykes. While the general inclination of the bedding sometimes continues uniform in direction and amount from one ridge to another, it is apt to change rapidly, as if the complex assemblage of intruded masses had been disrupted and had subsided in different directions.

The gabbro overlies the bedded basalts of the plateau all the way from Glen Brittle to the western side of Loch Scavaig. It then

<sup>1</sup> *Quart. Journ. Geol. Soc.* vol. 1. (1894) pp. 216, 645.

<sup>2</sup> *Op. cit.* p. 648, and pl. xxvi.

descends abruptly across these basalts and also across the Torridon Sandstone, on which they unconformably rest. These two groups of rocks are not only truncated by the gabbro, but are traversed by the intricate system of sills, dykes, and veins already referred to.

Where it abuts against the sandstones and basalts, the gabbro is arranged in vertical bands of different mineral composition and texture. Much of it is remarkably coarse, some bands displaying pyroxene-crystals more than an inch in length. There is no fine-grained selvage here indicative of more rapid cooling. So coarse, indeed, is the rock close up against the sandstone that the junction-line can hardly be supposed to be the normal contact of the intrusive rock. This inference is confirmed by the existence of a singular kind of breccia between the gabbro and the sandstones. It is a tumultuous mass of fragments of coarse and fine gabbro, Torridon Sandstone and Shale, and plateau-basalts, imbedded in a pale crystalline matrix of fine granular granophyre. Veins from this acid intrusion run off into the gabbro on the one side as well as into the Torridon Sandstone on the other. It would seem that this junction-line has been one of great movement, that the gabbro-sheets have subsided against a fault-wall of plateau-basalt and Torridon Sandstone, and that subsequently an intrusion of finely granular granophyre has come up the fissure, involving in its ascent fragments of all the materials around.

The rocks for a considerable distance to the south of the gabbro are intensely altered. The Torridon Sandstone has been so indurated as to pass into a bleached white quartzite, while the shales interstratified with it have been converted into a kind of porcellanite.

But the most interesting alterations are those to be observed in the plateau-basalts which, at a height of about 300 feet above the sea, are to be seen in nearly horizontal sheets that lie immediately on the upturned edges of the Torridon Sandstone. These lavas have suffered great metamorphism: their alternations of amygdaloidal and more compact sheets can still be recognized, though their enclosed amygdules have in places been almost effaced. They show the dull, indurated, splintery character, with the white weathered crust, which I formerly described as distinctive of this type of contact-metamorphism, and are traversed by numerous sills and veins of gabbro. No large mass of granophyre appears here at the surface. We can hardly be mistaken in looking upon this alteration as due either to the influence of the main body of the gabbro, or perhaps more probably to the abundant acid sills, dykes, and veins, possibly to both causes combined. It must be admitted that there may be a considerable body of granophyre underneath the locality, the surface-dykes and veins being indications of its vicinity.

In my former memoir I dwelt upon the remarkable alteration of the plateau-basalts as they approach the large masses of gabbro or granophyre.<sup>1</sup> During the summer of 1895 Mr. Harker, in the

<sup>1</sup> Trans. Roy. Soc. Edin. vol. xxxv. (1888) p. 167. Prof. Judd has referred the alteration of the rocks to solfataric action (Quart. Journ. Geol. Soc. vol. xlv. 1890, p. 341). I have been unable to detect any evidence of such action. The alteration is always intimately connected with the presence of intrusive masses,

progress of his mapping in the Strath district of Skye, had occasion to go over a number of the localities (Creaghan Dubha, etc.) cited by me, and, while corroborating my general conclusions regarding them, has been able to obtain much fresh evidence regarding the nature and extent of the metamorphism which the bedded basalts have undergone. His results will appear in due time, when the survey of Skye is further advanced. I have submitted to him some slices cut from typical examples of the altered plateau-basalts as they approach the gabbro of Loch Scavaig, and he has supplied me with the subjoined report regarding them :—

‘In hand-specimens the bedded basalts from the neighbourhood of the gabbro of Loch Scavaig [6613–6618] do not appear very different from the normal basalts of this region. The most conspicuous secondary mineral is yellowish-green epidote in patches, and especially in the amygdules.

‘The texture of the rocks varies, and the slices show that the microstructure also varies, the augite occurring sometimes in small ophitic plates, sometimes in small rounded granules. The chief secondary change in the body of the rock is shown by the augite, which is seen in various stages of conversion to greenish fibrous hornblende. Some round patches seem also to consist mainly of the latter mineral, and are probably pseudomorphs after olivine. Here the little fibres are confusedly matted together, without the parallelism proper to urallite derived from augite. No fresh olivine has been observed. The felspar and magnetite of the basalts show little or no sign of metamorphic processes, unless a rather unusual degree of clearness in the felspar-crystals is to be regarded in that light.

‘The contents of the metamorphosed amygdules are not always the same. Epidote is usually present in some abundance, and in well-shaped crystals. It has a pale citron tint in the slices, with marked pleochroism; but a given crystal is not always uniform in its optical characters. Frequently the interior is pale, and has a quite low birefringence: this is probably to be regarded as an intergrowth of zoisite in the epidote, and there are a few distinct crystals of zoisite seen in some places.

‘In the slide which best exhibits these features [6613] the crystals of epidote are in part enwrapped and enclosed by what are doubtless zeolitic minerals. At least two of these are to be distinguished. One, very nearly isotropic, and with a pale-brownish tint, is probably analcime. Associated with this is a colourless mineral with partial radiate arrangement and with twin-lamellation; the birefringence is somewhat higher than that of quartz, and the

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and it affects indifferently any part of the basalt-plateaux which may chance to lie next to these masses. The bedded lavas can be traced step by step from their usual unaltered condition in the plateaux to their metamorphosed state next to the eruptive rocks. The nature or degree of the metamorphism has doubtless somewhat varied with the composition and structure of the rocks affected, and with the character and mass of the eruptive material; but it is certainly not confined to the older parts of the plateaux nor to any supposed pre-basaltic group of andesites.

$\gamma$ -axis of optic elasticity makes a small angle with the twin-line. These characters agree with those of epistilbite. In other parts of the same large amygdule the epidote-crystals are imbedded in what seems to be a felspar. This latter mineral is rather obscure, and twin-lamellation is rarely to be detected; but it seems highly probable that felspar has here been developed by metamorphic agency at the expense of zeolites which once occupied the amygdule. I have observed undoubted examples of this in metamorphosed basalts from other parts of Skye, *e. g.* from Creagan Dubha, near the granophyre-mass of Beinn Dearg.<sup>1</sup> The felspar occurs there in the same fashion, and in the same relation to epidote [2700, 2701]. In the specimens now described the chief minerals in the metamorphosed amygdules are those already named: others occur more sparingly, associated with them. In some cases there is a grass-green, strongly pleochroic, actinolitic hornblende, accompanied by a little iron pyrites [6615].

'Epidote and various hornblendic and augitic minerals are characteristic products in the metamorphism of amygdaloidal basalts in other regions: felspar with this mode of occurrence I have not seen except in Skye, where it seems to connect itself naturally with the abundance of zeolites in the amygdules of the non-metamorphosed lavas. It is to be observed that in these basalts from Loch Scavaig the alteration is shown especially in the amygdules, the body of the rock not being greatly affected: this indicates a not very advanced stage of metamorphism. The production of uralitic hornblende, rather than brown mica, from the augite and its decomposition-products seems to be characteristic of the metamorphism of basaltic as distinguished from andesitic rocks, and is well illustrated by comparison of the two sets of lavas near the Shap Granite.'<sup>2</sup>

A re-examination of parts of the gabbro mountains of Rum has shown me that, though in a less marked degree than in Skye, the same banded structure may be detected in the thick beds or sills of which these eminences are composed. The remarkably schist-like bed of troctolite formerly described by me<sup>3</sup> lies between more massive sheets that show a much ruder parallel structure. The whole mountain of Allival overlying this troctolite is built up of successive parallel sheets of gabbro, among which banding is of frequent occurrence, the layers varying from less than an inch to a foot or more in breadth, and lying parallel to each other and to the upper and under surfaces of the sheets in which they occur. An occasional example of curvature in the banding may be observed.

Compared with the gabbros of the Cuillin Hills, those of Rum display a similar but less definite aggregation of their component minerals in definite layers or bands. In particular, the pyroxene and olivine, either separately or together, are crowded along particular bands of darker hue, while the paler bands between them are composed chiefly of felspar. The crystals or crystalline kernels are

<sup>1</sup> Compare Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 166.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 361.

<sup>3</sup> Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 123; Quart. Journ. Geol. Soc. vol. I. (1894) p. 649.

sometimes an inch in diameter, so that when closely grouped along particular layers they give rise to strikingly coarse-grained varieties of rock. Magnetite, on the whole, is rather less conspicuous than in the Cuillin gabbro; at least, it is not so prominently aggregated in special layers.

So rude is the parallel structure in these rocks of Rum that, although quite recognizable on a weathered surface where the constituent minerals are revealed by the way in which they respectively decay, it is often hardly to be detected on a freshly-broken exposure.

The western and more rugged part of the island of St. Kilda<sup>1</sup> is built up of various gabbros, dolerites, and basalts, traversed by dykes and veins of similar material. The gabbros include rocks of coarse, medium, and fine grain, like those of Skye, which lie in sheets or sills, but also apparently in large irregularly-shaped masses. In one or two places I noticed a faint banding, but my opportunities of studying these rocks were cut short by a change of weather which necessitated an abrupt departure, there being no safe anchorage at the island. I sailed round the coast, however, near enough to form a good idea of the general structure of the rock. Like the corresponding masses of the Cuillin Hills, the St. Kilda gabbro arrests attention by its singular blackness of tone, varied by its yellow coating of lichens and its grey crust of weathering, while its occasional slopes of débris are covered with a thick bright-green carpet of turf formed of matted sea-pink.

While the gabbros of St. Kilda are not a mere uniform boss, but rather a series of sills and irregular masses which have been successively injected into each other, they have subsequently been cut through by the basalt-dykes and veins already noticed. These, which are sometimes as abundant as in the gabbro of the Cuillin Hills, traverse the rock at all angles, and, as they generally weather faster than it does, they give rise to deep clefts which ascend the precipices, occasioning sea-caves below and sharp notches on the crests above.

These scenic features, so indicative of the geological structure that causes them, are specially well seen on the western face of the Dune or south-western promontory of the island, and likewise in the strangely rifted precipices to the north. They are, however, still more impressively displayed around the naked walls of the neighbouring islet of Borrera (1000 feet high), which consists entirely of gabbro pierced with dykes, and in its marvellous combination of spiry ridges, deep straight gullies, and splintered crests, reminds one at every turn of the scenery of Blaven and the Cuillin Hills.

Nowhere in St. Kilda or its dependent islets can any certain trace be obtained of a rock more ancient than the gabbros. So great has been the denudation that the eruptive core of this volcanic district has been reduced merely to a few scattered islets. If, as is probable, this core was once surrounded and covered by a plateau of basalt, no fragment of such a plateau remains, unless we may be

<sup>1</sup> For references to published information on the geology of this island see pp. 389, 390.



allowed to recognize it among some of the basalt-sheets included among the gabbros.

Like their counterparts in the Inner Hebrides, these rocks have not only been traversed by basic dykes, but have been invaded by a large mass of granophyre. The junction of the acid and basic materials repeats the evidence already cited from Mull, Rum, and Skye, and proves beyond all question that the acid rock is the younger of the two. The characters of this junction will be given in the next section of this paper.

It is interesting to observe that, while in St. Kilda no relic of any basaltic plateau has been preserved, in the Faroe Islands, on the other hand, no sign has been revealed by denudation that the volcanic plateau of that region has any eruptive core of gabbro or of granophyre. During my cruises round these islands and through their channels, I was ever on the outlook for any difference in topography that might indicate the presence of some eruptive boss like the gabbro- and granophyre-masses of the Inner Hebrides. But nothing of that nature could be discerned. Everywhere the long level lines of the bedded basalts mounted up to the crests of the ridges and the tops of the highest peaks. Though I cannot assert that no intrusions of gabbro or of granophyre exist among the Faroe Islands, I feel confident that any such masses which may occur must be of quite insignificant dimensions, and do not make the important feature in geology and topography which they do among the Inner Hebrides.

## VII. THE GRANOPHYRE INTRUSIONS.

Having recently brought the subject of the Tertiary granophyres before the Society,<sup>1</sup> I shall content myself in the present paper with an account of some additional examples of their occurrence and of their relations to the other members of the volcanic series.

St. Kilda supplies fresh evidence of much interest in this part of the volcanic history. The visitor, in approaching the island, especially from the southern or northern side, will notice the same two strongly contrasted topographical features as those that are so well exhibited in the centre of Skye. Along the western side rise the black rugged crags of gabbro. The eastern precipices are pale in colour, and are capped by rounded or conical hills, which towards the interior send down long screes of grey or russet-coloured débris. Their forms are so like those of the Red Hills of Skye that the geologist recognizes their true nature and respective limits, even before setting foot on them.

To Macculloch we are indebted for the first good description of the rocks of St. Kilda.<sup>2</sup> He clearly identified the pale rock of the eastern half of the island with the 'syenite' or granophyre of Skye, and he further remarked that it presented much resemblance to some parts of the granite of Arran. He observed 'fragments of trap penetrated by veins of syenite,' but he did not see these

<sup>1</sup> Quart. Journ. Geol. Soc. vol. 1. (1894) pp. 212-229.

<sup>2</sup> 'Description of the Western Islands,' vol. ii. (1819) p. 54.

rocks in place, and, in spite of their apparent testimony to the posteriority of the acid intrusions, he was inclined to believe that the veins were not real veins, but that the 'trap' and 'syenite' had a common origin and would be found to pass into each other, as he thought also occurred in Mull and Rum. In recent years Mr. Alexander Ross has visited St. Kilda and published an excellent account of its geology.<sup>1</sup> He collected specimens illustrating the varieties of gabbro, dolerite, and basalt, and showing the intrusion of the acid into the basic rocks. He was disposed to believe the 'granite' to be of younger date than the gabbros, but left the question open for further consideration.

The acid rock which forms the eastern side of this island, variously termed 'syenite' and 'granite,' weathers in thick bed-like sheets, divided by transverse joints into large quadrangular blocks, like many granites. On closer inspection it is found to resemble still more precisely the acid rocks of the Inner Hebrides. It possesses the same drusy micropegmatitic structure as the granophyres of Skye, Rum, and Mull. The ferro-magnesian constituents are present in small quantity, hence the pale hue of the stone. The quartz and feldspar project in well-terminated crystals into the drusy cavities, which are sometimes further adorned with delicate tufts of clear, crystallized epidote. In many respects the rock resembles the young granites of Arran and the Mourne Mountains.

Mr. Harker's notes on the microscopic structure of this granophyre are as follows:—'The prevailing feldspar is orthoclase, often very turbid from secondary products. Even what appear to be distinct crystals are sometimes seen in the slices to be invaded in the margin by quartz in rough micrographic intergrowths, and much of the finer intergrowth occurs as a fringe to the crystals. In this case the feldspar of the micropegmatite can often be verified to be in crystalline continuity with the crystal which has served as a nucleus [6624]. Quartz occurs in distinct crystals and grains as well as in the micropegmatite. There is a more granitoid variety of the rock, in which only a very rude approach to micrographic intergrowths is seen [6623]. In both varieties there is but little trace of any ferro-magnesian mineral; the more typical granophyre has what seems to be destroyed augite, while the granitoid rock contains a little deep-brown biotite. Scattered crystal-grains of magnetite occur in both.'

Narrow ribbon-like veins of a finer material, sometimes only an inch in breadth, traverse the ordinary granophyre. Similar veins run

<sup>1</sup> Brit. Assoc. Rep. 1885 (Aberdeen meeting), p. 1040; and a much fuller paper in the Proc. Inverness Field Club, vol. iii. (1884) p. 72. In this latter paper a letter from Prof. Judd is quoted, in which he states that the rock supposed to be granite 'is seen under the microscope to be a quite different rock—a quartz-diorite,' p. 78. Some of the specimens from St. Kilda collected by Mr. Ross were exhibited at the meeting of this Society on January 25th, 1893. With regard to these, Prof. Judd, in the course of the discussion on his paper on 'Inclusions of Tertiary Granite in the Gabbro of the Cuillin Hills,' remarked:—'They show a dark rock traversed by veins of a light one, but the dark rock is not a gabbro, and the light rock is not a granite,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 198.

through the rock of the Red Hills in Skye; they are sharply defined from the enclosing rock, as if the latter had already solidified before their intrusion.

With regard to the microscopic structure of some thin slices prepared from these veins, Mr. Harker remarks that 'the material of the veins is of a type intermediate between granophyre and microgranite [6622, 6623]. The chief bulk is a finely granular aggregate of quartz and felspar, the latter very turbid; but in this aggregate are imbedded numerous patches of micropegmatite, often of perfect and delicate structure. These areas of micropegmatite show some approach to a radiate or rudely spherulitic structure, and, in some cases, are clustered round a crystal of felspar or quartz. Some granules of magnetite and rare flakes of brown biotite are the only other constituents of the rock. Although they must be of somewhat later date, there is evidently nothing in the petrographical characters of these fine-textured veins to separate them widely from the ordinary granophyres of the region.'

These veins may be compared with the spherulitic dyke which traverses the granophyre of Meall Dearg at the head of Glen Sligachan, and which, though undoubtedly somewhat later than the rock that contains it, yet presents the very same structures as are visible at the margin of that rock.<sup>1</sup> The material of this dyke, and of the finer veins of St. Kilda and the Red Hills, probably belongs to a later period of protrusion from a deeper unconsolidated portion of the same acid magma as that which at first supplied the general body of granophyre.

Undoubtedly the most interesting feature in the granophyre of St. Kilda is its junction with the mass of basic rock to the west of it. It requires no close search to find *in situ* the dark rock with acid veins of which Macculloch found scattered fragments. The line of junction between the basic and acid masses runs across the island from the western side of the chief bay to the northern coast, where it is exposed in a line of high cliffs.

The beach to the west of the landing-place in the bay is strewn with blocks of various dark, finely crystalline basic rocks, traversed by pale veins of granophyre. At the western end of the shingle, the rocks are met with in places forming a line of low cliff and a rugged foreshore. The basic rock consists of various gabbros and basalts of rather fine grain, profusely traversed with veins of white granophyre. Some of these veins are 2 feet or more in breadth, and, when of that size, show the distinctive granular texture and drusy structure of the main part of the acid rock. But from these dimensions they can be traced through every stage of diminution until they become mere threads. When they are only an inch or two broad they assume a finely granular texture, like that of the veins which run through the body of the granophyre.

The amount of injected material in the dark basic rocks is here and there so great as to form a kind of breccia (fig. 28, p. 392), which, from the contrast of tone between its two constituents, makes a conspicuous object on the shore. The enclosed fragments are of

<sup>1</sup> Quart. Journ. Geol. Soc. vol. 1. (1894) p. 220.

all sizes from mere grains up to blocks a foot or more in length. They are generally angular, like rock-chips from a quarry. The granophyre here and there assumes a darker or greener tint, as if it had dissolved and absorbed some portion of the older rock.

Fig. 28.—*Pale granophyre injected into dark basalt. St. Kilda.*

[From a photograph by Col. EVANS.]



Though closer in grain where it comes in contact with the gabbro, the granophyre never assumes any vitreous or distinctly spherulitic textures along its margin. A series of thin slices prepared from my specimens has been examined for me by Mr. Harker, who has furnished the following notes regarding them:—‘The basalt traversed by the granophyre is a fine-textured variety, with small porphyritic feldspars. These latter seem to be usually unaltered, retaining the glass-cavities which in some of the crystals are abundant. The groundmass, however, shows minerals of metamorphic origin which must be derived mainly from the original augite. A brown mica is the most conspicuous; but with it are associated some brownish-green hornblende and certain chloritic and perhaps serpentinous substances. It is chiefly near the margin of a fragment of basalt that the mica gives place to these minerals. The basalt still retains plenty of unaltered granules of augite in the central parts of a fragment. It is not certain that the secondary minerals named come exclusively from the augite of the basalt; judging from their form and mode of occurrence I should say that they may in part have replaced olivine or even rhombic pyroxene.

'The acid rock, though styled granophyre above, belongs to a granitoid variety of that group of rocks, and has but little indication of micrographic structures. Compared with the other granophyres from St. Kilda, sliced and examined, these examples show a less acid composition. This is expressed mineralogically in the presence of a somewhat larger proportion of ferro-magnesian minerals and of soda-lime felspar. These features might indeed be matched in many normal granophyres among the Western Isles, but in the present case it can hardly be doubted that they are to be explained, at least in some degree, by the acid magma having taken up a certain amount of material from the basalt. Many of these Tertiary granophyres have undoubtedly been modified by the incorporation of pieces of basalt and gabbro, and a collection made in the Strath district of Skye will furnish examples for future study. Prof. Sollas's description of similar phenomena in the Carlingford district has already proved the importance of this kind of action.<sup>1</sup> In the present instance, both brown mica and hornblende occur plentifully in the granophyre, and especially round the basalt-fragments. This latter point is conclusive as to the derivation of the basic material, and further proves a certain degree of viscosity in the acid magma at the time of its intrusion.'

On the northern side of St. Kilda the junction-line of the granophyre runs up the cliffs, abundant pale veins of the acid material striking off from the main body of the rock and traversing the dark gabbros.

The testimony of the rocks of St. Kilda to the posteriority of the granophyre to the gabbros and basalts is thus clear and emphatic. It entirely confirms my published observations regarding the order of sequence of these rocks in Mull, Rum, and Skye. But the St. Kilda sections display, even more strikingly than can be usually seen in these islands, the intricate network of veins which proceed from the granophyre and the shattered condition of the basic rocks which these veins penetrate.

I have already alluded to the remarkable association of acid and basic material in numerous dykes as well as in some sills in the district of Strath in Skye. I formerly described some examples of this association from that district,<sup>2</sup> and many more have recently been observed and mapped by Mr. Clough and Mr. Harker during the progress of the Geological Survey. The conjunction commonly shows a central and thicker band of granophyre or spherulitic felsite with two thinner parallel bands of some dark intermediate or basic rock. This triple arrangement occurs both in dykes and sills.

As an illustration of the association of the two kinds of rock in dykes I may cite the example which appears on the southern edge of the Market Stance of Broadford (fig. 29, p. 394). Here the characteristic triple arrangement is typically developed. A central light-coloured band, about 8 to 10 feet broad, consists of a spherulitic granophyre in which the spherulites are crowded together and project from the weathered surface like peas, though they do not here show the curious rod-like aggregation so marked in some other

<sup>1</sup> Trans. Roy. Irish Acad. vol. xxx. (1894) pp. 477-512.

<sup>2</sup> Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 174.

dykes. On either side of this acid centre a narrow basalt-dyke intervenes as a wall, next to the Torridon Sandstone which here forms the country-rock.

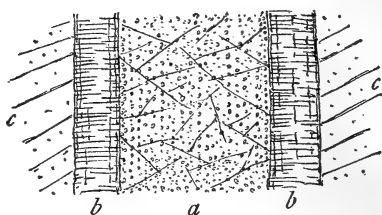
In this instance, and generally throughout the district, there is nothing to indicate that the different bands of the dyke have any relation to each other as connected uprisings of material from the same original magma which was undergoing a process of differentiation beneath the terrestrial crust. On the contrary, the several parts of each dyke are as distinctly marked off from each other as they could have been had they been injected at widely separated intervals of volcanic activity.

The same indication of an independent origin is displayed by the rocks when they form compound sills, with a thick central sheet of acid material overlain and underlain by some more basic rock. I have shown that the posteriority of the acid sill may sometimes be demonstrated by its sending out veins into the darker sill above or below it.<sup>1</sup> But a more striking proof of the independence of the two kinds of rock may be seen at Suishnish Point, in the Isle of Raasay (fig. 30). Here the Pabba Shales of the Lower Lias (*a a*) are surmounted by a sheet of granophyre (*b*), of which the top has been removed by denudation. This rock occupies about 5 square miles in the southern half of the island, where it has recently been mapped by Mr. H. B. Woodward for the Geological Survey. It has been intruded across the Jurassic Series, a large part of its mass coming in irregularly about the top of the thick white sandstones of the Inferior Oolite. But it descends beneath the Secondary rocks altogether, and in some places intervenes between the base of the Infra-Liassic conglomerates and the Torridon Sandstone.

The central portions of this Raasay granophyre possess the ordinary structures of the corresponding rocks in Skye. They show a fine crystalline-granular micropegmatitic base, through which large feldspars and quartzes are dispersed. But at the upper and under junctions with the sedimentary rocks beautiful spherulitic structures are developed. This is well seen on the shore near the Point of Suishnish, where, below the Liassic limestones, the top of the granophyre appears, and where its bottom is seen to lie on the Torridon Sandstone.

Where the eruptive rock rests on the Pabba Shales, a basalt-dyke which rises through these strata turns abruptly at the base of the acid rock and then pursues its course to one side as a sill (*c*)

Fig. 29.—Compound dyke. Market Stance, Broadford, Skye.

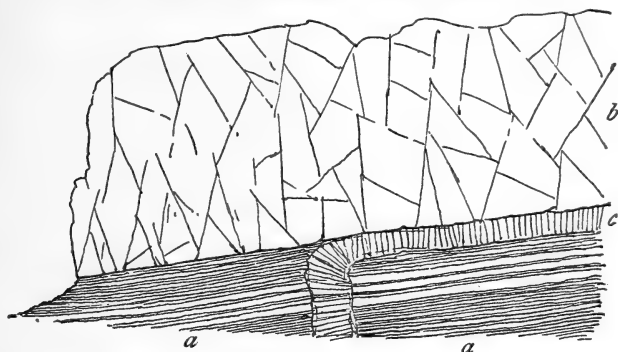


*a.* Granophyre; *b b.* Basalt; *c c.* Torridon sandstone.

<sup>1</sup> Trans. Roy. Soc. Edinb. vol. xxxv. (1888) p. 174.

between the granophyre and the shales. There can be little doubt that this intrusion is later than the granophyre. We have here a basic sill interposed at the bottom of the acid sheet; but in this case we can connect the sill with the actual fissure up which its molten material was impelled.

Fig. 30.—*Section of granophyre-sill resting on Lower Lias shales, with a dyke of basalt passing laterally into a sill.*



Some remarkable illustrations of the threefold arrangement of compound sills have recently been observed and mapped by Mr. Harker in the Broadford district, one of great interest occurring on the shore at Irishman's Point in Broadford Bay.

#### VIII. MODERN VOLCANIC ACTION IN ICELAND, AS ILLUSTRATIVE OF THE HISTORY OF THE BASALT-PLATEAUX OF NORTH-WESTERN EUROPE.

Beyond the Faroe Islands, at the further end of the Wyville-Thomson ridge, which stretches across the bottom of that part of the Atlantic Ocean, another basalt-plateau rises in Iceland, presenting many of the familiar characters of those described in this paper, and probably belonging to the same geological period. The bottom of these Icelandic Tertiary basalts is everywhere concealed under the sea. Yet their visible portion shows them to be probably more than 3000 metres in thickness.

An especial interest belongs to this Icelandic plateau because volcanic action is still vigorous upon it at the present day. A long series of eruptions has taken place there since the Glacial Period. There were likewise abundant pre-glacial eruptions. So far indeed as we know, there is no evidence of any important cessation of the subterranean activity since Tertiary time.<sup>1</sup> The existing volcanic phenomena may with probability be regarded as the survival of those which were so widely manifested over the Icelandic area and the North-west of Europe in the older Tertiary ages. A careful study of them may therefore be expected to throw light on the history of the Tertiary basaltic plateaux; while, on the other hand, the thorough dissection of these plateaux by the denuding agencies

<sup>1</sup> See Johnston-Lavis, *Scottish Geogr. Mag.* 1895, p. 442.

will not improbably be found to explain some parts of the subterranean mechanism of the Icelandic volcanoes.

In calling attention to some of the more obvious analogies which may be traced between the modern and the ancient volcanoes, I am more particularly indebted to the excellent memoirs of the resident Icelandic geologist Mr. Th. Thoroddsen, who has examined so large a part of the island.<sup>1</sup> The account given by A. Helland of the Laki craters has likewise been of much service to me.<sup>2</sup> Among other recent observers I may cite Dr. Tempest Anderson,<sup>3</sup> who has made himself familiar with extensive tracts of Iceland, and Dr. Johnston-Lavis, who has published the narrative of a journey in company with him.<sup>4</sup>

It is a mistake to suppose that the Icelandic volcanoes are generally built on the plan of such mountains as Vesuvius or Etna. Evidently Mr. Thoroddsen can hardly repress his impatience on finding these two Italian cones cited in almost every handbook of geology as types of modern volcanoes and their operations. The regular volcanic cone composed of alternations of lavas and tuffs hardly occurs in Iceland at all. The fundamental feature in the Icelandic eruptions is the production of fissures which reach the surface and discharge streams of lava from many points.

Two systems of fissures appear to be specially marked, one running from south-west to north-east, the other from south to north.<sup>5</sup> Hekla and Laki belong to the former. The dislocations have often followed the boundaries of the 'horsts' or solid blocks of country which have withstood terrestrial displacement. The vast outbursts of Odadahraun and Myvatn have almost all issued from fissures of that nature.

The violent eruption of 1875 in Askja found its exit at the intersection of two lines of fissure. Many large fissures were opened on the surface in a nearly north-and-south direction, which could be followed for 80 kilometres. Some of them became the theatre of intense volcanic activity.<sup>6</sup>

Many lines of fissure are traceable at the surface as clefts or 'gjas,' that run nearly straight for long distances, with a width of 1 to 3 yards, and of unknown depth.<sup>7</sup> Occasionally a fissure

<sup>1</sup> See in particular his paper on the volcanoes of N.E. Iceland (Bihang till k. Svensk. Vet. Akad. Handl. vol. xiv. pt. ii. no. 5, 1888) and that on Snaefell and Faxebugt in the south-west of the island (*op. cit.* vol. xvii. pt. ii. no. 2, 1891); also papers in the Dansk. Geografisk. Tidsskrift, vols. xii., xiii. (1893-95), and in the Verhandl. Gesellsch. Erdkunde zu Berlin, 1894 & 1895.

<sup>2</sup> 'Lakis Kratere og Lavaströmmen,' Universitetsprogram, Christiania, 1885. See Mr. Thoroddsen's remarks on this paper, Verhandl. Gesellsch. Erdk. Berlin, 1894, p. 289.

<sup>3</sup> Brit. Assoc. Rep. 1894 (Oxford meeting), p. 650.

<sup>4</sup> Johnston-Lavis, Scot. Geogr. Mag. 1895.

<sup>5</sup> In the Snaefell promontory they run nearly east and west, Thoroddsen, Bihang Svensk. Vet. Akad. Handl. vol. xvii. pt. ii. no. 2, p. 91.

<sup>6</sup> Thoroddsen, *op. cit.* vol. xiv. pt. ii. no. 5, p. 63.

<sup>7</sup> On the various modes of origin of these chasms, see Tempest Anderson, Brit. Assoc. Rep. 1894, p. 650. Mr. Thoroddsen describes a fissure in the south of Iceland running N.E. for 30 kilometres, with a depth of 130 to 200 metres. It has discharged three great lava-streams, covering a total area of 693 square kilometres.



has not been continuously opened to the surface. An interesting example of such intermittent chasms is supplied by the great rent which gave forth the enormous volume of lava in 1783. The mountain of Laki, composed of palagonite-tuff, stands on the line of the dislocation, but has not been entirely ruptured. The fissure has closed up beneath the mountain, a short distance above the bottom of the slope, as is shown by the position of a couple of small craters.<sup>1</sup>

Some fissures have remained mere open chasms without any discharge of volcanic material; others have served as passages for the escape of lava and the ejection of loose slags and cinders.<sup>2</sup>

In some instances, according to Mr. Thoroddsen, lava wells out from the whole length of a fissure without giving rise to the formation of cones, the molten material issuing either from one or from both sides, sometimes flowing out tranquilly, but more usually giving rise to long ramparts of slags and blocks of lava piled up on either side. In the great majority of cases, however, a row of cones is formed along the line of the open fissure. Thus, on the Laki fissure, which runs for about 20 miles in a north-easterly direction, the cones amount to some hundreds in number. Hekla itself appears to have been built up along a main fissure, with parallel subsidiary rents on which rows of cones have been formed.<sup>3</sup>

The cones consist generally of slags, cinders, and blocks of lava. According to Mr. Helland's observations, along the marvellous line of the Laki fissure they are on the whole not quite circular but oblong, their major axis coinciding with the line of the chasm on which they have been piled up. In many places they are exceedingly irregular in form, changes in the direction of outflow of lava or of escape of steam having caused the cones partially to efface each other.

As regards their size, the cones present a wide range. Some of them are only a few yards in diameter, others several hundred yards. Generally they are comparatively low mounds. On the Laki fissure some are only a couple of yards high; the majority are much less than 50 yards in height, and hardly one is as much as 100 yards.<sup>4</sup> And yet these little monticules, as Mr. Helland remarks, represent the pipes from which milliards of cubic metres of lava have issued. While other European volcanoes form conspicuous features in the landscape, the Icelandic volcanoes of the Laki district, from which the vastest floods of lava have issued in modern times, are so low that they might escape notice unless they were actually sought for.<sup>5</sup>

As they have generally arisen along lines of fissure, the cones are for the most part ranged in rows. The hundreds of cones that

<sup>1</sup> A. Helland, 'Lakis Kratere og Lavaströmme,' p. 25.

<sup>2</sup> Mr. Thoroddsen has observed that in the Reykjanes peninsula, in the S.W. of Iceland, by the subsidence of one side of a fissure, a row of four craters has been cut through, leaving their segments perched upon the upper side ('Globus,' vol. lxxix. no. 5).

<sup>3</sup> Johnston-Lavis, *op. cit.* p. 457.

<sup>4</sup> Mr. Thoroddsen, however, states that there are about 100 between 20 and 100 metres in height.

<sup>5</sup> A. Helland, *op. cit.* p. 27.

mark the line of the Laki fissure present an extraordinary picture of volcanic energy of this type. In other instances the cones occur in groups, though this distribution may have arisen from the irregular uprise of scattered vents along a series of parallel fissures. Thus to the north-east of Laki a series of old cones, entirely surrounded by the lavas of 1783, lie in groups, the most northerly of which consists of about one hundred exceedingly small craters that have sent out streams of lava towards the north-north-east.<sup>1</sup>

It would appear from Mr. Helland's observations that the same fissure has sometimes been made use of at more than one period of eruption. He describes some old craters on the line of the Laki fissure, which had been active long before the outbreak of 1783.<sup>2</sup>

When the lava issues from fissures it is in such a condition of plasticity that it can be drawn out into threads and spun into ropes. When the slope over which it flows is steep it often splits up into blocks on the surface. Where the ground is flat the lava spreads out uniformly on all sides, forming wide plains as level as a floor. Thus the vast lava-desert of Odadahraun covers a plain 3640 square kilometres in area, or, if the small lava-streams north from Vatnajökull be included, 4390 square kilometres. This vast flood of lava (about 1700 English square miles in extent) would, according to Mr. Thoroddsen, cover Denmark to a depth of 16 feet. The whole of this enormous discharge has been given forth from more than twenty vents situated for the most part on parallel fissures.

Not less striking is the picture of fissure-eruption to be met with at Laki—the scene of the great lava-floods of 1783. ‘Conceive now,’ says Mr. Helland, ‘these hundreds of craters, or, as they are called by the Icelanders, “borge,” lying one behind another in a long row; every one of them having sent out two or more streams of lava, now to the one side, now to the other. Understand further that these streams merge into each other, so as to flow wholly round the cones and form fields of lava miles in width, which, like vast frozen floods, flow down to the country districts, and you may form some idea of this remarkable region.’<sup>3</sup>

In the course of time the successive streams of lava poured out upon one of these wide volcanic plains gradually increase the height of the ground, while preserving its generally level aspect. The loose slag-cones of earlier eruptions are effaced or swallowed up, as one lava-stream follows another. Eventually, when, by the operation of running water or by fissure and subsidence, transverse sections are cut through these lava-sheets, the observer can gene-

<sup>1</sup> A. Helland, ‘Lakis Kratere og Lavaströmmen,’ p. 25.    <sup>2</sup> *Op. cit.* p. 26.

<sup>3</sup> *Op. cit.* p. 24. Mr. Helland allows an average thickness of 30 metres for the mass of lava which issued in two streams, one 80 kilometres (nearly 50 miles), the other 45 kilometres (about 28 miles) long. He estimates the total volume of lava discharged in the 1783 eruption at 27 milliards of cubic metres, equal to a block 10 kilometres (6 miles 376 yards) long, 5 kilometres (3 miles 188 yards) broad, and 540 metres (1771 feet) high; *op. cit.* p. 31. Mr. Thoroddsen remarks that the older estimates of the volume of lava discharged by this eruption have been greatly exaggerated. He puts the area covered by lava at 565 square kilometres, and the contents at  $12\frac{1}{3}$  cubic kilometres (*Verhandl. Gesellsch. Erdk. Berlin*, 1894, p. 296).

rally notice only horizontal beds of lava piled one above another, including the dykes connected with them and intercalated masses of loose slag, that remain as relics of the old craters.

In some places the lava has gradually built up upon its parent fissure an enormous dome, having a gentle inclination in every direction, as may be seen especially in the district between Floderne Skjalfanafljot and Jökulsà. Most of the large volcanic piles of North Iceland are of this nature. The highest of them are 1209 and 1491 metres high by from 6 to 15 kilometres in diameter. The elliptical crater of the highest of these eminences measures 1100 by 380 metres.<sup>1</sup>

There is still another feature of the Icelandic volcanic regions which may be cited as an interesting parallel to the sequence of eruptive discharges among the Inner Hebrides. While the main mass of the lavas is more or less basic, many of them being true basalts, they have been at different times pierced by intrusions and outflows of much more acid liparites, and even of granophyre. Examples of these rocks of post-glacial age have recently been traced on the ground by Thoroddsen,<sup>2</sup> and their petrographical characters have been studied by Bäckström.<sup>3</sup> The wide distribution of such rocks all over the island, their occurrence in isolated bosses among the more basic lavas, and their remarkable internal structures have been noted by several observers.<sup>4</sup>

It will thus be seen how entirely the modern volcanic eruptions of Iceland agree with the phenomena presented by our Tertiary basalt-plateaux. It is to the Icelandic type of fissure-eruptions, and not to great central composite cones like Vesuvius or Etna, that we must look for the modern analogies that will best serve as commentary and explanation for the latest chapter in the long volcanic history of the British Isles.

## IX. THE FAULTS OF THE PLATEAUX.

There can be no doubt that considerable alterations of level have taken place over the volcanic areas of North-western Europe since the eruptions that produced the basalt-plateaux. The mere fact that in many places the lower members of these terrestrial lavas have been submerged under the sea may be taken to prove a subsidence there since older Tertiary time. Along the western coast of Skye this depression is well shown by the almost entire concealment of the bottom of the plateau under the Atlantic. In the Faroe Isles the subsidence has advanced still further, for not a trace of the

<sup>1</sup> Thoroddsen, Bihang till Svensk. Vet. Akad. Handl. vol. xiv. pt. ii. no. 5, pp. 19, 23.

<sup>2</sup> Geol. Fören. Stockholm Förhandl. vol. xiii. (1891) p. 609; Bihang Svensk. Vet. Akad. Handl. vol. xvii. (1891) pt. ii. p. 21; Dansk. Geogr. Tidsskr. vol. xiii. (1895). He has also found peaks of gabbro and boulders of the same rock brought down from the Vatnajökull. The gabbro rests upon basalt, seems to be associated with granophyres, and is cut by dykes of liparite. It is regarded by Mr. Thoroddsen as belonging to the older Tertiary series and to occur probably in the same way as the gabbro of Mull (*op. cit.* p. 35).

<sup>3</sup> Geol. Fören. Stockholm Förhandl. vol. xiii. (1891) p. 637.

<sup>4</sup> See in particular C. W. Schmidt, Zeitschr. Deutsch. geol. Gesellsch. vol. xxxvii. (1885) p. 737.

underlying platform on which the basalts rest remains above water. In Iceland, too, the complete submergence of the base of the Tertiary volcanic sheets points to the widespread subsidence of that region.

Another strong argument in favour of considerable subsidence may be derived from a comparison of the submarine topography with that of the tracts above sea-level. It is obvious that the same forms of contour as those which are conspicuous on the land are prolonged under the Atlantic. If we are correct in regarding the valleys as great lines of subaerial erosion, their prolongations as fjords and submarine troughs must be regarded as having had a similar origin. We can thus carry down the surface of erosion several hundred feet lower than the line along which it disappears under the waves.

I know no locality where this kind of reasoning is so impressively enforced upon the mind as the western end of the Scur of Eigg. The old river-bed and its pitchstone terminate abruptly at the top of a great precipice. Assuredly they must once have continued much farther westward, as well as the sheets of basalt that form the main part of the cliff. Yet the sea in front of this truncated face of rock rapidly deepens to fully 500 feet in some places. Had any such hollow existed in the volcanic period it would have been filled up by the long-continued outflowings of basalt. We can only account for this submarine topography by regarding it as having been carved out, together with the topography of the land, at a time when the level of the latter was at least 500 feet higher than it is now.

The subsidence which is thus indicated along the whole of the North-west of Europe probably varied in amount from one region to another. We seem to have traces of such an inequality in the varying inclinations of different segments of the basalt-plateaux. The angles of inclination are almost always gentle, but they differ so much in direction from island to island, and even among the districts of the same island, as to indicate that certain portions of the volcanic plain sank rather more than other portions.

Thus in the Faroe Islands, where the bare cliffs allow the varying angles of inclination to be easily determined, a general gentle dip of the basalts in a south-easterly direction has been noted by previous observers. This inclination, however, is replaced among the southern islands by an equally gentle dip towards the north-east. The centre of depression would thus seem to lie somewhere about Sandö and Skuö. The highest angle of inclination which I noticed anywhere was at Myggenaes, where the basalts dip E.S.E. at about  $15^{\circ}$ .

Though I have not observed any features among the basalt-plateaux that can be compared to the remarkable rifts and subsidences of Iceland, it can be shown that these piles of volcanic material have undoubtedly been fractured, and that portions of them have subsided along these lines of dislocation. Careful examination of the basalt-escarpments of the Inner Hebrides discloses the existence of numerous faults which, though generally of small displacement, nevertheless completely break the continuity of all the rocks in a precipice of 700 or 1000 feet in height. Not infre-

quently such dislocations give rise to clefts in the cliffs. Some good illustrations of this feature may be noticed on the northern side of the island of Canna, where the highest part of the precipice has been fissured by a series of dislocations, having a hade towards the west and a throw which may in some cases amount to about 20 or 25 feet. The cumulative effect of this system of faulting, combined with a gentle westerly dip, is to bring down to the sea-level the upper band of conglomerate which farther east lies at the top of the cliff. Again, the basalt-escarpment on the western side of Skye, from Dunvegan Head to Loch Eynort, is traversed by a number of small faults. On the eastern side of Skye and in Raasay a series of faults, some of them having perhaps a throw of several hundred feet, has been mapped by Mr. H. B. Woodward.

The largest dislocation observed by me among the fragments of the basalt-plateaux is that which runs at the back of the Morven outlier, in the west of Argyleshire.<sup>1</sup> It runs from the head of Loch Aline to the mouth of Loch Sunart along the line of valley that contains the salt-water fjord Loch Teacus and the freshwater lakes Loch Durinemast and Loch Arienas. While the Cretaceous deposits and the bottom of their overlying basalts rise but little above the sea-level on the south-western side of this line, they are perched as outliers on hilltops on the north-eastern side, where they rise to 1300 feet above the sea. The amount of vertical displacement here probably exceeds 1000 feet. The fault runs in a north-westerly direction, and has obviously been the guiding influence in the erosion of the broad and deep valley which marks its course at the surface.

To what extent the dislocations that traverse the Tertiary basalts of the Inner Hebrides are to be regarded as comparable to those which in Iceland have been referred to subsidence caused by the tapping and outflow of the lower still liquid parts of lava-sheets must be matter for further enquiry. So far as my own observations have yet gone, the faults do not seem explicable by any mere superficial action of the kind supposed. Where they descend through many hundreds of feet of successive sheets of basalt and dislocate the Secondary rocks underneath, they must obviously have been produced by much more general and deep-seated causes.

It is conceivable that, if these dislocations took place during the volcanic period, they broke up the lava-plains into sections, some of which sank down so as to leave a vertical wall at the surface on one side of the rent, or even to form open 'gjas,' like those of Iceland. But it is noteworthy that the fissures which have been filled with basalt and now appear as dykes, comparatively seldom show any displacement in the relative levels of their two sides. In Iceland, also, the great lava-emitting fissures seem to be in general free from marked displacement of that kind.

The faults in the Inner Hebrides, so far as I have observed, are all normal, and indicate nothing more than gentle subsidence. But among the Faroe Islands I have come upon several instances of reversed faults, which, in spite of the gentle inclinations of the

<sup>1</sup> This fault was noticed by Prof. Judd traversing the cliffs of the Sound of Mull, and is referred to in my memoir already cited.

basalts, probably point to much more vigorous displacement within the terrestrial crust.

On the eastern side of Svinö a fault with a low hade runs from sea-level up to the top of the cliff, a height of several hundred feet. It has a down-throw of a few yards, but is a reversed fault, as will be seen from fig. 31. Another similar instance may be noticed on the north-eastern headland of Sandö, where, however, on the upcast side, the basalts appear as if they had been driven upward, a portion of them having been pushed up into a low arch (fig. 32).

When the Tertiary basalt-plateaux come to be worked out in detail, many examples of dislocation will doubtless be discovered. We shall then learn more of the amount and effects of the terrestrial disturbances which have affected North-western Europe since older Tertiary time. In the meantime evidence enough has been adduced to prepare us for proofs of very considerable recent displacements even among regions of crystalline schists like that which has been disrupted by the Morven fault above alluded to. While the study of the Tertiary volcanic rocks demonstrates the vast general denudation of the country since older Tertiary time, the proofs that these rocks have been faulted acquire a special interest in relation to the origin and evolution of the topography of the region.

#### X. THE EFFECTS OF DENUDATION.

Among the more impressive lessons which the basalt-plateaux of North-western Europe teach the geologist, the enormous erosion of the surface of this part of the continental area since older Tertiary time takes a foremost place. He may be ready almost without question to accept the evidence adduced in favour of a vast amount of denudation among such soft and incoherent strata as those of the older Tertiary formations of the South-east of England. But he is hardly prepared for the proofs which meet him among the north-western isles that such thick masses of solid volcanic rocks have been removed during the same geological interval.

Fig. 31.—*Reversed fault on the eastern side of Svinö, Faroe Isles.*

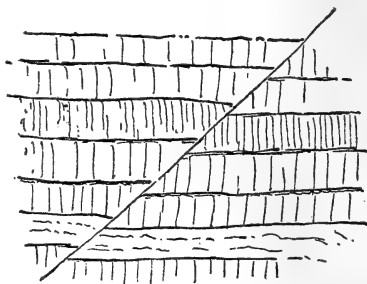
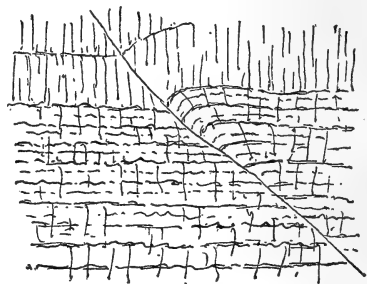


Fig. 32.—*Reversed fault on the N.E. headland of Sandö, Faroe Isles.*



To gain some idea of the amount of this waste we must, in the first place, picture to our minds the extent of ground over which the lavas were poured, and the depth to which they were piled upon it. Whether the now isolated basalt-plateaux of Britain were once united into a continuous plain of lava may never be ascertainable. It is quite certain that every one of these plateaux was formerly much more extensive than it is now, for each of them presents as its terminal edge a line of wall formed by the truncated ends of horizontal basalt-sheets. And there seems no improbability in the assumption that the whole of the great hollow from the centre of Antrim up to the Minch was flooded with lavas which flowed from many vents between the hills of ancient crystalline rocks forming the line of the Outer Hebrides on the west, and those of the mainland of Scotland on the east.

The depth to which some parts of this long hollow were overflowed with lava exceeded 3000 feet. The original inequalities of surface were buried under the volcanic materials which were spread out in a vast plain or series of plains, like those that have been deluged by modern eruptions in Iceland. Owing, however, to a general but unequal movement of subsidence, the lava-fields sank down here and there to, perhaps, an extent of several hundred feet, so that the old land-surface on which they began to be poured out now lies in those places below the level of the sea.

I have shown that even during the volcanic period, while the lavas were still flowing from time to time, erosion was in active progress over the surface of the volcanic plain. The buried river-channel of the Seuir of Eigg, and the records of water-action described in the present paper, prove that rivers descending from the mountains of the Western Highlands carried the detritus of these uplands for many miles across the lava-fields, swept away the loose material of volcanic cones, and cut channels for themselves out of the black rugged floor of basalt.

The erosion thus early begun has probably been carried on continuously ever since. The present streams may be looked upon as practically the same as those which were flowing in the Tertiary period. There may have been slight changes of level, oscillations both upward and downward in the relative positions of land and sea, and shiftings of the watercourses to one side or other; but there seems no reason to doubt that the existing basalt-plateaux, which were built up as terrestrial areas, have remained land-surfaces with little intermission ever since, although their lower portions may have been in large measure submerged.

In the existing valleys, fjords, and sea-straits by which these plateaux have been so deeply and abundantly trenched, we may recognize some of the drainage-lines traced out by the rivers which flowed across the volcanic plains. The results achieved by this prolonged denudation are of the most stupendous kind. The original lava-floor has been cut down into a fragmentary tableland. Hundreds of feet of solid rock have been removed from its general surface. Outliers of it may be seen scattered over the mountains of Morven, whence they look into the heart of the Highlands. Others cap the hills of Rum, where they face the open Atlantic.

Far away from the main body of the plateau in Skye, a solitary remnant, perched on the highest summit of Raasay, bears eloquent witness that the basaltic tableland once stretched far to the east of its present limits.

Some of the valleys thus excavated out of the volcanic sheets are many miles long, a mile or more wide, and, from crest to bottom, several thousand feet deep. The deep winding sea-lochs of Mull and the west of Skye form striking monuments of this part of the waste.

Yet, impressive as are these proofs of denudation, they are perhaps inferior in this respect to the evidence furnished in the same region by the great cores of gabbro and granophyre. These eruptive masses must once have lain under a thick pile of basalt, for they obviously belong to part of the deeper-seated mechanism of the volcanic vents. Yet of this vast overlying mantle every trace has been stripped off from many of these cores, while in others mere patches of it remain where they were welded to the intrusive bosses by the heat of eruption.

Moreover, the cores of gabbro and granophyre have been intersected by abundant dykes which reach the present surface of the ground, even up to the crests of the mountains. It is certain that the uprise of these thousands of dykes could not have taken place except under cover of a great depth of rock now removed, for otherwise the basalt would have rushed out from the fissures at the foot of the hills and filled up the valleys, instead of rising between the fissure-walls to the summits of the ridges. Not a single vestige of any lava-stream younger than the gabbros and granophyres has yet been discovered. It is quite possible, perhaps even likely, that the post-granophyre dykes did lead to the outflow of lava here and there at the surface. But any proofs of such emission have been utterly destroyed in the extensive degradation which the plateaux have undergone. By this process of reasoning we can demonstrate that valleys in Skye and Mull 3000 feet deep have been excavated out of the Tertiary volcanic series.

Among the Faroe Islands the evidence of erosion is, in some respects, even more striking. I shall never forget the first impression made on my mind when the dense curtain of mist within which I had approached the southern end of the archipelago rapidly cleared away, and the sunlit slopes and precipices of Suderö, the two Dimons, Skuö and Sandö, rose out of a deep blue sea. Each island showed its prolongation of the same long level lines of rock-terrace. The eye at once seized on these rock-features as the dominant element in the geology and the topography, for they revealed at a glance the true structure of the islands, and gave a measure of the amount and irregularity of the erosion of the original basalt-plateau. And this first impression of stupendous degradation only deepened as one advanced farther north into the more mountainous group of islands. Probably nowhere else in Europe is the potency of denudation as a factor in the evolution of topographical features so marvellously and instructively displayed as among the north-eastern members of the Faroe group. The waste might have been as gigantic among amorphous rocks, such as granites and gabbros, or even among schistose masses, like the Lewisian gneiss. But in these materials



the eye cannot detect any datum-line by which to estimate the loss. In the north-eastern part of the Faroe Isles, however, the horizontal bars of bare rock are continued from cliff to cliff across the deep fjords into the adjoining islands. These terraces afford not only a demonstration that vast hollows have been excavated out of one great volcanic plateau, but also a measure of at least the minimum amount of material so removed.

Availing ourselves of these datum-lines, we easily perceive that in many parts of the Faroe Isles the amount of volcanic material left behind, stupendous though it be, is less than the amount which has been removed. Thus the island of Kalsö is merely a long narrow ridge separating two broad valleys which are now occupied by fjords. The material carved out of these valleys would make several islands as large as Kalsö. Again, the lofty precipice of Myling Head, 2260 feet high, built up of bedded basalts from the summit to below sea-level, faces the north-western Atlantic, and the sea rapidly deepens in front of it to the surface of the submarine ridge 200 to 300 feet below. The truncated ends of the vast pile of basalt-sheets which form that loftiest sea-wall of Europe bear testimony to the colossal denudation which has swept away all of the volcanic plateau that once extended farther towards the west.

Nevertheless, enormous as has been the waste of this plateau of the Faroe Islands, we may still trace some of its terrestrial features that date back probably to the volcanic period. Even more distinctly than among the Western Isles of Scotland, we may recognize the position of the original valleys and trace some of the main drainage-lines of the area when it formed a wide and continuous tract of land.

A line of watershed can be followed in a south-westerly direction from the eastern side of Viderö, across Borö to the centre of Osterö, and thence by the Sund across Stromö and Vaagö. From this line the fjords and valleys diverge towards the north-west and south-east. There cannot be any doubt that on the whole this line corresponds with the general trend of the water-parting at the time when the Tertiary streams were flowing over the still continuous volcanic plain. Considerable depression of the whole region has since then sent the sea up the lower and wider valleys, converting them into fjords, and isolating their intervening ridges into islands.

The topography of the Faroe Islands seems to me eminently deserving of careful study in the light of its geological origin. There is assuredly no other region in Europe where the interesting problems presented by this subject could be studied so easily, where the geological structure is throughout so simple, where the combined influences of the atmosphere and of the sea could be so admirably worked out and distinguished, and where the imagination, kindled to enthusiasm by the contemplation of noble scenery, could be so constantly and imperiously controlled by the accurate observation of ascertainable fact.

#### DISCUSSION.

THE PRESIDENT, after complimenting the Author on the clearness of the exposition of his views, said that from his descriptions we not only obtain a view of these old volcanic vents and lava-flows, but

also a graphic picture of the features of the ancient lands now only represented by these Western Isles. We see, by the traces of old river-courses, their former connexion with the mainland, and are able to realize the enormous work which subaerial and marine denudation have effected over this great area of the north-west.

Prof. SOLLAS remarked that, in listening to this important contribution, he had been greatly impressed with the uniformity in character of the rocks belonging to the great Gaelic-Icelandic province. The granophyre on the table from St. Kilda was so precisely similar to the granophyre of Mourne and Carlingford that, without labels, it would be impossible to distinguish the rock in hand-specimens. It was therefore the less surprising to find that the same order of extrusion was maintained in places so far apart as Carlingford and St. Kilda. No deduction in favour of a regular order of differentiation from basic to acid igneous products could, however, be drawn from this province; and now less than ever, since Sir Archibald Geikie had pointed out that granophyres were among the most recent igneous rocks in Iceland. The speaker welcomed the confirmation which Mr. Harker had afforded of observations previously made at Barnavave. The constancy in direction of dykes over wide areas stood in direct relation to the constancy in direction of the thrusts which prevailed over Europe-Asia during the Tertiary period. In Ireland, as Sir A. Geikie had already shown, the dykes ran from S.E. to N.W., and this direction closely corresponded to that of normals to the axes of the folds: the change in direction of the dykes in Iceland was of great interest, and might furnish evidence of the direction of the concealed folds of that island, which had in all probability been subject to thrusts coming from the south and west.

Mr. W. W. WATTS remarked that at the time this paper was being read Prof. Cole was probably communicating one on the rhyolites of Antrim at the Royal Dublin Society. Were there no rhyolitic lavas on the Scottish side of this great province? The reported difference between pre-granophyre and post-granophyre dykes, if substantiated, would be of great value in Ireland as well as in Scotland. He did not quite understand what connexion there was between the old river of Canna and that of Eigg, if one was overflowed by pitch-stone and the other by plateau-basalt. He referred to the work of Prof. Iddings on the composite dykes of the Electric Peak.

Dr. DU RICHE PRELLER wished to ask the Author, with reference to the third section of the paper, what was the material immediately underlying the two alternations of conglomerate at the eastern end of Canna. Assuming the conglomerate to be fluvial, one would expect it to rest on sand, which, whether loose or hardened to sand-stone, should be of a certain depth, the more so as the conglomerate was in each case as much as 100 feet in thickness.

The AUTHOR thanked the Fellows for their cordial reception of his paper, and briefly replied to the questions that had been put by the previous speakers.

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## EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

SESSION 1896-97.

1896.

Wednesday, November .....	4-18
"      December .....	2-16

1897.

"      January .....	6-20
"      February ( <i>Anniversary</i> , Feb. 19) .....	3-24
"      March .....	10-24
"      April .....	7-28
"      May .....	12-26
"      June .....	9-28

[*Business will commence at Eight o'Clock precisely each Evening.*]

20. *The FAUNA of the KEISLEY LIMESTONE.*—PART I. By F. R. COWPER REED, Esq., M.A., F.G.S. (Read February 26th, 1896.)

[PLATES XX. & XXI.]

DURING a recent rearrangement of the fossils from this limestone in the Woodwardian Museum my interest was especially aroused by the number of peculiar and unnamed specimens amongst them; and I was thus led to examine them with particular care, and subsequently to visit Keisley myself and collect more in the field, as well as to inspect Prof. Harkness's collection at Carlisle, and the specimens in some small private collections. The following descriptions have therefore been based on the examination of as large an amount of material as was available. Prof. Harkness's collection at Carlisle and that of Prof. Nicholson and Mr. Marr at Cambridge are those upon which the well-known lists of Keisley Limestone fossils have been founded; the last list was published by Prof. Nicholson and Mr. Marr in 1891.<sup>1</sup>

By carefully removing the matrix I have been able to bring out many minute characters previously invisible, and have also discovered several entirely new species, which make an important addition to our knowledge of the bed.

My thanks are due to Mr. Marr, Prof. Nicholson, Mr. Goodchild, Chancellor Ferguson, of Carlisle, Mr. E. T. Newton, and others for help and information.

In this first part of my communication the trilobites alone are dealt with, being the largest and most characteristic section of the fauna. In the second and concluding part the rest of the fossils will be described, and the general relations of the fauna discussed.

### CRUSTACEA—TRILOBITA.

A list of fossils from the Keisley Limestone was published in 1865<sup>2</sup> by Prof. Harkness. Amongst them he recorded the following trilobites:—

<i>Cheirurus clavifrons</i> , Dalm.	<i>Illænus Davisi</i> , Salt.
— <i>bimucronatus</i> , Murch.	<i>Lichas</i> , sp.
— <i>octolobatus</i> ?, M'Coy.	<i>Harpes</i> , sp.
<i>Ampyx tumidus</i> ?, Forbes.	

Again, in 1877,<sup>3</sup> Profs. Harkness and Nicholson gave the following list:—

<i>Sphærexochus mirus</i> , Beyr.	<i>Illænus Davisi</i> , Salt.
<i>Cheirurus juvenis</i> , Salt.	<i>Calymene Blumenbachi</i> , Brongn.
— <i>bimucronatus</i> , Murch.	<i>Agnostus</i> , sp.
— <i>gelasinus</i> , Portl.	<i>Ampyx Sarsii</i> , Portl.
— <i>cancurus</i> , Salt.	<i>Remopleurides</i> , sp.
— <i>octolobatus</i> , M'Coy.	<i>Bronteus</i> , sp.
<i>Lichas laxatus</i> , M'Coy.	<i>Proetus</i> , sp.
<i>Illænus Bowmani</i> , Salt.	

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 507.

<sup>2</sup> *Ibid.* vol. xxi. (1865) p. 243.

<sup>3</sup> *Ibid.* vol. xxxiii. (1877) p. 468.

And in 1891<sup>1</sup> Prof. Nicholson and Mr. Marr published a new and revised list of the fossils from this bed. All the specimens collected by them at that time are in the Woodwardian Museum. The following species of trilobites are recorded :—

*Ampyx tumidus*, Forbes.  
*Cheirurus bimucronatus*, Murch.  
 — *cancrurus*, Salt.  
 — *clavifrons*, Dalm. (?).  
*Cyphaspis* (?) cf. *triradiatus*,  
 Törnquist.  
*Cyphoniscus socialis*, Salt.  
*Homalonotus punctillosus*,  
 Törnquist.

*Illæus Bowmani*, Salt.  
 — cf. *conifrons*, Billings.  
 —, sp.  
*Lichas laciniatus*, Wahl.  
 — *laxatus*, M'Coy.  
*Remopleurides* cf. *longicostatus*,  
 Portl.  
*Sphærexochus calvus*, M'Coy.

The list which I am now able to give as the result of my investigations is as follows :—

## AGNOSTIDÆ.

*Agnostus* cf. *Galba*, Billings.

## TRINUCLEIDÆ.

*Ampyx binodulosus*, sp. n.  
*Tiresias insculptus*, M'Coy.

## OLENIDÆ.

*Remopleurides Colbii*, Portl.  
 — *longicostatus*, Portl.  
*Cyphoniscus socialis*, Salt.

## CALYMENIDÆ.

*Calymene Blumenbachi*, var. *Caractaci*,  
 Salt.  
*Homalonotus* ? *punctillosus*, Törnquist.

## ILLENIIDÆ.

*Illæus Bowmani*, Salt.  
 —, var. *brevicapitatus*, v. n.  
 —, var. *longicapitatus*, v. n.  
 — *fallax*, Holm.  
 — *Ræmeri*, Volborth.  
 — *cæcus*, Holm.  
 — *galeatus*, sp. n.  
 —, sp., hypostome.

## CHEIRURIDÆ.

*Cheirurus bimucronatus*, Murchison,  
 var. *α*, Salt.  
 — *cancrurus*, Salt.  
 — *keisleyensis*, sp. n.  
 — cf. *glaber*, Angelin.

*Cheirurus* cf. *clavifrons*, Dalm. ?  
 — (*Pseudosphærexochus*) *conformis*,  
 Angelin.  
 — (—) *subquadratus*, sp. n.  
*Sphærocoryphe granulata*, Angelin ?  
*Sphærexochus mirus*, Beyr.  
 — *latirugatus*, sp. n.  
*Staurocephalus Murchisoni*, Barrande.

## ACIDASPIDÆ.

*Acidaspis convexa*, sp. n.  
 —, sp.

## LICHADÆ.

*Lichas laxatus*, M'Coy.  
 — *affinis*, Angelin.  
 — *conformis*, Angelin, var. *keisley-*  
*ensis*.  
 — *hibernicus*, Portl.  
 — *bulbiceps*, Phillips, MS.  
 — *bifurcatus*, sp. n.

## PROETIDÆ.

*Cyphaspis* ? *Harknessi*, sp. n.  
 — (*Törnquistia*, subgen. nov.)  
*Nicholsoni*, sp. n.  
*Phillipsinella parabola*, Barrande.

## HARPEDIDÆ.

*Harpes Wegelini*, Angelin.  
 — *costatus*, Angelin ?  
 —, sp. *α*.  
 —, sp. *β*.

## AGNOSTIDÆ.

*Agnostus* cf. *Galba*, Billings.

A pygidium of this species in a remarkably good state of preservation was found by me during a recent visit to Keisley. It

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 507.



possesses all the characters of Billings's species<sup>1</sup> which occurs in the Quebec group, except that the axis in our specimen is rather shorter than in his figure, and therein approaches *Agn. tardus* of Barrande.<sup>2</sup> The ornamentation of the surface, of which Billings says (*loc. cit.*) that one specimen showed indications, is very clearly exhibited, and consists of fine reticulating or undulating raised lines or fine wrinklins on the zone of the lateral lobes; the striæ run more or less concentrically to the margin of the pygidium. The remainder of the test is smooth.

The specific differences of this species from *Agn. tardus* (see Billings, *loc. cit.*) are:—(1) The elongated central tubercle on the axis is elevated at its abrupt posterior extremity to twice its height at its anterior end.

(2) The zone of the lateral lobes is ornamented by fine wrinklins or raised lines.

#### TRINUCLEIDÆ.

##### AMPYX BINODULOSUS, sp. n. (Pl. XXI. fig. 1.)

The specimen in the Woodwardian Museum which had been assigned to Forbes's species *A. tumidus* cannot, in my opinion, be allowed to remain in that species for the following reasons:—(1) The cheeks unite with the glabella in front of the middle of its length; (2) at the base of the glabella are two distinct circular nodules or lobes, which occupy nearly its whole breadth so as almost to touch each other in the centre.

There is another smaller specimen of this new species in the Harkness collection at Carlisle.

The glabella is almost lanceolate in shape, but is truncated abruptly behind by the distinct neck-furrow. In front the glabella tapers gradually into a grooved spine (broken off short in our specimen).

The glabella is most convex from side to side at the level where it becomes free and projects in front of the cheeks; from its posterior end to the base of the spine it is very gently and regularly convex. A faint keel runs longitudinally down its centre, and at the base of the glabella lie the pair of circular flattened lobes or areas, one on each side of the keel. These circular areas or lobes scarcely rise above the general level of the glabella at this part, but extend nearly across its whole breadth, giving it a very characteristic appearance.

The cheeks are triangular, somewhat swollen and distinctly marked off by shallow axial furrows from the glabella, with which they unite at a point rather in front of the middle of its length. Near the anterior end of each axial furrow and in its course there lies a small but deep pit. The genal angles appear to have been produced into rounded spines.

The neck-segment is narrow, but distinctly marked off from the

<sup>1</sup> Billings, Geol. Surv. Canada, Palæozoic Fossils, vol. i. (1865) p. 297, fig. 288.

<sup>2</sup> Barrande, 'Syst. Sil. Bohême,' vol. i. (1852) p. 913, pl. xlix.

cheeks and glabella by a neck-furrow. The posterior border of the head-shield is not straight, but formed of three gentle backward curves—the lateral ones bounding the neck-segment behind the cheeks and the middle one the neck-lobe of the glabella.

The whole surface of the cheeks and glabella is finely punctated.

*Affinities.*—The two points of difference already given distinguish this species from *A. tumidus*, to which it seems otherwise allied. *A. (Raphiophorus) depressus* of Angelin is distinguished by the smaller size of the circular basal lobes, their greater distance apart, the shortness of the glabella, and its practical non-carination.

#### TIRESIAS INSCULPTUS, M'Coy.

This peculiar trilobite is apparently allied to *Ampyx*, as M'Coy says. It is very rare in the Kildare Limestone, and I have only seen one specimen from the Keisley Limestone, and that is in the Carlisle Museum.

In M'Coy's figure<sup>1</sup> there are two small indentations near the base of the glabella, but they are not mentioned in his description, nor are they seen in the Keisley specimen. The last-named shows that the cheeks are prolonged as a narrow flattened band in front of the glabella, but there is no true border to the head-shield. The axial furrows are also wider than M'Coy figures. The wavy thread-like lines which ornament the glabella are roughly concentric to its front end, and those on the triangular convex cheek are roughly parallel to the lateral edge of the head-shield. The other features are given in M'Coy's description, and need not be repeated.

Length of head-shield 9·5 millim.; width (estimated) of the same at the base 14·0 millim.

#### OLENIDÆ.

##### REMOPLEURIDES COLBII, Portl.

There are two beautifully-preserved thoracic rings and pleuræ in the Woodwardian Museum, showing the characteristic ornamentation of the species with great distinctness, but no other portion of this trilobite is known.

##### REMOPLEURIDES LONGICOSTATUS, Portl.

In the collection made by Messrs. Marr and Nicholson from the Keisley Limestone there is an exceedingly fine head (*minus* the free cheeks) of this species, showing the ornamentation most distinctly. Salter's description (Mem. Geol. Surv. dec. viii. text with pl. viii. p. 9) makes any further remarks on my part superfluous. The species also occurs in Prof. Harkness's collection at Carlisle.

##### CYPHONISCUS SOCIALIS, Salter.

The head-shields of this peculiar little trilobite are not very common at Keisley. Nevertheless I have found several there

<sup>1</sup> M'Coy, 'Syn. Silur. Foss. Irel.' pl. iv. fig. 1, p. 43.

recently, but have no further particulars to add to Salter's minute description of its characters.

Only one pygidium, 4 millim. in length, has so far been discovered at Keisley, and this must have belonged to a large individual.

#### CALYMENTIDÆ.

##### CALYMENE BLUMENBACHI, var. CARACTACI, Salter.

The genus *Calymene* has been recorded from the Keisley Limestone by Prof. Harkness. A glabella and pygidium belonging to the above species have recently been found in the state of internal casts, but exhibiting all the usual well-known characters.

##### HOMALONOTUS ? PUNCTILLOSUS, Törnquist.

Prof. Nicholson and Mr. Marr were the first to record this curious trilobite from the Keisley Limestone, and in fact from England.<sup>1</sup> But it had been collected many years previously from that bed by Prof. Harkness, for I found unnamed specimens of it in his collection at Carlisle. It had also been long ago found at the Chair of Kildare, but was named *Asaphus*? and *Olenus*? It is still open to doubt whether it is correctly placed in the genus *Homalonotus*, and it appears closely allied with Billings's genera *Bathyurus* and *Bathyurellus*, to one of which it may subsequently have to be referred. Törnquist describes and figures it in the Swedish Geological Survey Memoirs<sup>2</sup> from the *Leptæna*-Limestone.

#### ILLENIDÆ.

##### ILLENUS BOWMANI, Salter.

The determination of the species or varieties of the genus *Illænus* has been a matter of considerable difficulty, inasmuch as the common *I. Bowmani* varies considerably in outline and convexity of the head-shield. Some specimens also show an ornamented surface, whereas Salter described the surface as smooth. After carefully examining a very large series of specimens I believe that I can establish two fairly well-marked varieties of the typical form, and these I have respectively called *I. Bowmani*, var. *longicapitatus*, and *I. Bowmani*, var. *brevicapitatus*. The typical form of *I. Bowmani* also occurs, and there are found some individuals which can with difficulty be assigned to any of the three, for they possess intermediate characters.

Thus one specimen of a head-shield has all the characters and the ordinary shape of the typical *I. Bowmani*, but its surface is ornamented with raised lines as in the variety *brevicapitatus*.

Again there are some head-shields of a pointed form like the variety *longicapitatus*, but without the conspicuously sudden downward curvature of the front end of the head-shield.

<sup>1</sup> Marr & Nicholson, 'The Cross Fell Inlier,' Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 507.

<sup>2</sup> S. L. Törnquist, 'Undersökn. öfv. Siljansområdet Trilobitfauna,' Sver. geol. Undersökn. 1884, p. 44, pl. i. figs. 46 & 47, pl. ii. figs. 1 & 2.

Again others have the abrupt posterior truncation as in *I. Davisi*, but all the other characters of *I. Bowmani*.

The amount of curvature and convexity of the head-shield is a variable feature, and not of much classificatory importance.

*ILLÆNUS BOWMANI*, var. *LONGICAPITATUS*. (Pl. XX. fig. 5.)

Head-shield parabolic to semi-oval, the hinder two-thirds of the surface flattened, but the front curves down suddenly and steeply. Neck-furrow plainly visible on the cheeks. Surface of the head-shield minutely punctated. Eye rather more forward than in the type-form. Other characters identical.

The measurements of one specimen are given to show the proportionate size of the different parts of the middle shield.

	millim.
Length of shield.....	33·0
Width of do. at level of eyes .....	41·0
Length of glabella .....	15·5
Width of do. at base .....	18·0
Width of fixed cheek at eyes .....	12·0

*Note*.—Some of the head-shields of *I. angustifrons*, Holm, resemble in general appearance those of this variety, but the eyes seem to be larger and more forward in position.

*ILLÆNUS BOWMANI*, var. *BREVICAPITATUS*. (Pl. XX. fig. 4.)

Head-shield transversely elliptical; length is to breadth as 2:3. The anterior edge forms a much flattened forward curve. Glabella rather shorter than the type-form. Sculpture of middle shield as follows:—Close to anterior margin and parallel to it are a few continuous raised thread-like lines, conveniently called ‘terraced lines’ by Holm, and between these and the anterior end of the glabella are present in some specimens shorter scattered similar lines, arranged more or less concentrically with the margin. On the glabella itself there are three groups of similar lines, a median group of short lines arched forward, and a pair of lateral groups of slightly curved oblique lines. Across the base of the glabella are a few longer horizontal straight lines. Very minute scattered puncta occur over the whole surface of the head-shield.

In all points except the above this variety agrees with the type-form.

*Measurements of two Specimens.*

	I. millim.	II. millim.
Length of head-shield.....	26·0	19·5
Width of do. at level of eyes.....	34·0	24·0
Distance between facial sutures where they cut the front margin .....	29·0	22·0
Length of glabella .....	10·0	7·5
Width of do. at base .....	17·0	10·5

*ILLÆNUS FALLAX*, Holm.

There is one specimen of a small pygidium in the Woodwardian Museum which shows all the well-marked features of Holm's *I. fallax*<sup>1</sup> from the *Leptæna*-Limestone of Dalecarlia.

In the shape of the pygidium, the position of the fulcrum, and the relative size and triangular outline of the axis, with the faint ridge from its apex to the posterior border, it entirely agrees with the Swedish specimens.

	millim.
Length of pygidium .....	6.0
Breadth of do. ....	8.5
Length of axis .....	2.5
Width of do. ....	2.5

A specimen of the hypostome of an *Illænus* in the Carlisle Museum closely agrees with that of this species figured by Holm (*op. cit.* pl. vi. fig. 116). It is subquadrate in form with a swollen central portion, and is truncated in front and obtusely pointed behind. A border of regular width (except at the anterior lateral angles, where it expands considerably, but is imperfectly preserved) surrounds it.

The posterior end of the swollen central portion is furnished with a marginal band, as Holm shows. A few large granules also ornament the surface of this central portion.

Length=5.5 millim.; width=5.0 millim.

*ILLÆNUS RØEMERI*, Volb.

Both the middle shield and the free cheek of this species are now known from Keisley, but they had not previously been identified. However, a comparison of our specimens with the figures and descriptions of *I. Rømeri* (with which Holm<sup>2</sup> identifies the Swedish species *I. vivax*<sup>3</sup> from the *Leptæna*-Limestone) shows that the identification is correct. The shape of the head-shield, the relative size of the glabella, the course of the facial sutures, the position and size of the eyes, the characters of the free cheek, and the ornamentation exactly correspond. Two imperfect specimens of hypostomes from Keisley also bear a very close resemblance to the hypostome of this species as figured by Holm (*loc. cit.*). In Russia *I. Rømeri* occurs in the Lyckholm zone.

*ILLÆNUS CÆCUS*, Holm.

A solitary broken specimen of a middle shield agrees so exactly in all points with Holm's species *I. cæcus*<sup>4</sup> from the Lyckholm zone of the Island of Dagö that I do not feel any hesitation in

<sup>1</sup> Holm, 'Svenska Arterna af Trilobitslägtet *Illænus*,' Bih. k. sv. Vet.-Akad. Handl. vol. vii. (1882) no. 3, p. 82, pl. ii. figs. 15-20.

<sup>2</sup> Holm, 'Ostbalt. Illæn.' Mém. Acad. Imp. Sci. St. Pétersbourg, vol. xxxiii (1886) no. 8, p. 125, pl. ix. figs. 4-14.

<sup>3</sup> 'Svenska Arterna *Illæn*,' p. 74, pl. vi. figs. 1-7.

<sup>4</sup> 'Ostbalt. Illæn.' p. 162, pl. xi. fig. 11 a-d.

identifying the two. A badly preserved pygidium of an *Illenus* from Keisley also shows the characters of that part as described and figured by Holm.

*Measurements.*

	millim.
Length of middle shield .....	17.0
Width (greatest) of do. ....	30.5
Length of glabella .....	7.0
Width of base of do. ....	8.0
Length of pygidium .....	15.0
Width of do. ....	29.0
Width of front end of axis .....	7.0

*ILLENUS GALEATUS*, sp. n. (Pl. XX. figs. 1, 2 & 3.)

A dozen or more specimens of an *Illenus* in the Woodwardian Museum, which have their head-shields inflated to an extraordinary extent, possess a curious combination of characters. There is a great conical elevation situated nearly in the centre of the middle shield, and from its summit the surface slopes down regularly to the margins, but more steeply to the back and front than to the sides. Billings's species *I. conifrons* from the Chazy Limestone of Canada<sup>1</sup> resembles these Keisley forms in the abnormal amount of inflation, and Prof. Nicholson, who presented us with some of our specimens from Keisley, was accordingly led to compare them.<sup>2</sup> But in reality these British individuals are widely separated from the Canadian species by several essential structural features which are pointed out below.

The description of the Keisley form is as follows:—

The middle shield is nearly semicircular in front; its posterior margin is almost straight; the width is about half as much again as the length. It slopes up regularly from all sides to a subcentral conical elevation, the summit of which is obtusely rounded and situated immediately in front of the glabella. The profile of the middle shield across its middle, seen from behind, is like the small end of a fowl's egg; but viewed from the side the profile is semi-elliptical. The posterior slope is a little steeper than the anterior, and these two slopes are more convex than the lateral slopes, the latter being decidedly flattened. The vertical height of the middle shield is about half its greatest width.

The glabella is short, occupying only about two-thirds of the length of the posterior slope. It is about one and a quarter times as long as wide. It is almost rectangular and parallel-sided in shape; but it suffers a very little contraction in the middle through the gentle inward curvature of the axial furrows. It is undefined in front, but is bounded posteriorly by a shallow, though distinct neck-furrow which is arched slightly forward and marks off a narrow occipital ring. The glabella has a convexity independent

<sup>1</sup> Billings, 'Canadian Naturalist and Geologist,' vol. iv. (1859) p. 378; and Rep. Progr. Geol. Surv. Canada, 1863, ch. ix. p. 151, fig. 111, *a*, *b*.

<sup>2</sup> Marr and Nicholson, 'The Cross Fell Inlier,' Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 507.

of that of the general surface of the middle shield and of that of the fixed cheeks above which it rises. The convexity of the glabella is continued in front of the free termination of the axial furrows up to the summit of the middle shield, where it is lost.

The axial furrows are distinct, of moderate depth and breadth, have a curved course, and bend slightly outward at both their ends, though more strongly posteriorly. They extend up about two-thirds of the posterior slope of the middle shield.

Each of the fixed cheeks is at its base nearly as wide as the glabella, and, owing to outward curvature of the facial suture from the posterior margin, it rapidly increases in width forward as far as a point a little in front of the anterior end of the axial furrows. Here it has a width twice that of the glabella. The fixed cheeks fall down steeply and abruptly at their base to the narrow neck-segment.

There is no trace of an eye-lobe, and the species must have been blind.

The facial sutures cut the front margin at a distance from each other of about twice the width of the glabella. Each suture curves strongly outward and backward to the level of the front end of the glabella, behind which level it runs backward and inward, at first in a convex outward course and then with a slight inward curve, so as to cut the posterior margin at a distance from the axial furrow nearly equal to the width of the glabella.

The front margin of the middle shield is furnished with a distinct marginal furrow which marks off a narrow, raised, rounded border.

The free cheeks are not preserved; but, judging from the curvature of the front margin, the course of the facial suture, and their shape in allied forms, they must have been long and narrow.

The whole surface of the middle shield is ornamented with very closely-set puncta.

#### *Measurements of two Specimens.*

	I. millim.	II. millim.
Length of middle shield.....	24·0	18·0
Greatest width of do. ....	35·5	25·0
Greatest height of do.....	15·0	9·0
Length of glabella (to end of axial furrows)...	13·0	7·0
Width of do. at base .....	11·0	8·0
Greatest width of fixed cheek .....	19·5	12·0

(At a level a little in front of the anterior end of the glabella.)

*Note.*—There are several smaller specimens not quite so much elevated in the centre of the middle shield as those above described. But in all other respects they agree with them completely, and must be considered, at any rate for the present, merely as young individuals or a variety of the same species.

*Illænus galeatus* is a very common form at Keisley. There are specimens of it in Prof. Harkness's collection at Carlisle, but it is labelled *Ill. Davisii*. There are numerous excellently preserved

head-shields in the Woodwardian Museum, Cambridge, collected by Messrs. Marr and Nicholson and by myself.

*Affinities*.—From *I. conifrons*, Billings, our species is distinguished by the absence of eyes, the shortness of the axial furrows, the non-gibbosity and shortness of the glabella, etc. The amount of inflation of the head in the two forms is very similar and gives them a spurious look of affinity. Our Keisley form belongs, however, to that group of blind *Illæni* which have been described from Bohemia, Russia, and Sweden; *I. Angelini* (Holm)<sup>1</sup> and *I. leptopleura* (Linrs.) are the two blind species known from Sweden. With the former our British species agrees in the relative length and width of the glabella and the fixed cheeks, in the course of the axial furrows and of the facial suture, and in the absence of eyes; but differs in the amount of inflation and length of the head-shield. *I. cæcus* (Holm)<sup>2</sup> from the 'Lyckholmer Schicht F'<sup>3</sup> of the Baltic area comes very close to our species except in the amount of inflation, breadth, and curvature of the head-shield. The three Bohemian species, *I. Katzeri* (Barr.), *I. Zeidlereri* (Barr.), and *I. aratus* (Barr.), bear comparison; and all the seven appear to be closely allied by structural peculiarities. But the absence of eyes, which leads to a modification in the course of the facial suture and shape of the free cheeks, is said not to be accompanied by any changes in other parts of the body; and Barrande and Holm do not consider that there is sufficient justification for the creation of a new genus, particularly as a similar disappearance of the eyes and modification of the facial sutures and free cheeks is found in the genus *Conocephalites*.

#### ILLÆNUS, sp. (Pl. XX. fig. 6.)

One epistome of an *Illænus* in the Woodwardian Museum resembles somewhat closely that of *I. Davisi* (Salter), but it is longer and more pointed posteriorly. In shape this Keisley epistome is broadly triangular; its anterior side is gently arched forward, and its posterior sides converge backward with a slight concave-outward curve to meet at the rounded obtuse apex at an angle of about 135°.

All the three sides are slightly bevelled, but otherwise the epistome has a flat surface. Nine or ten strongly-marked furrows, with raised ridges between them, run across the surface from side to side. Those nearest the front border run across continuously almost in a straight line from one lateral angle to the other; the more posterior furrows bend backward in the middle with an increasingly sharp and strong curvature as they are followed backward. Between these strongly-bent posterior furrows and those in front are a few short furrows and ridges in the middle of the epistome. The anterior edge of the epistome is furnished with a broad smooth

<sup>1</sup> Holm, 'Svenska Arterna af Trilobitslägtet *Illænus*,' Bih. k. sv. Vet.-Akad. Handl. vol. vii. (1882) no. 3, p. 120, pl. iv. fig. 29.

<sup>2</sup> Holm, 'Ostbalt. Illæn.' Mém. Acad. Imp. Sci. St. Pétersbourg, ser. vii. vol. xxxiii. (1886) no. 8, p. 162, pl. xi. fig. 11 a-d.

<sup>3</sup> Barrande, 'Syst. Sil. Bohême,' pt. i. suppl.



border. The length of this epistome is 9.5 millim., and its width from side to side is 33 millim.

#### CHEIRURIDÆ.

*CHEIRURUS BIMUCRONATUS*, Murch., var. *α*, Salter.

It seems that this species, though occurring in the Keisley Limestone, is not so plentiful as *Ch. keisleyensis*. There is only a single pygidium belonging to it in the Woodwardian Museum, and no undoubted head-shields. Our specimen belongs to the variety *α* of Salter,<sup>1</sup> in which the terminal mucro between the third pair of spines is absent.

*CHEIRURUS CANCRURUS*, Salter.

Two pygidia of this species are in the Woodwardian Museum, but call for no special notice. Fragments of others are at Carlisle.

*Note*.—A portion of a glabella agrees fairly well with that assigned provisionally by Salter to this species.<sup>2</sup> The elongated shape of the glabella, the great length of the frontal lobe, and the finely granulated surface are the most striking points of similarity, but the side-furrows in our Keisley specimen are much longer than those described and figured by Salter, for each furrow of the front pair extends across the glabella at least a third of its breadth. The figure given by Törnquist<sup>3</sup> of *Ch. insignis* (Beyr.) much resembles our specimen. The glabella is much more inflated and convex than that of *Ch. bimucronatus* or that of *Ch. keisleyensis*. *Ch. conformis* of Angelin<sup>4</sup> may also be compared with it.

*CHEIRURUS KEISLEYENSIS*, sp. n. (Pl. XX. figs. 7, 8 & 9.)

This new species is founded on two incomplete pygidia, but some associated head-shields with less peculiar characters most probably belong to it. It seems that some of the head-shields have previously been assigned to *Ch. bimucronatus*, which they much resemble. But the features presented by the pygidium are very marked, and distinct from any British species previously described.

The pygidium is about 12 millim. long, and is furnished with three distinct pairs of pleuræ with free ends. The fourth pair of pleuræ and axial segments are represented by a single median, sub-terminal, triangular piece, embraced laterally and posteriorly by the third pair of pleuræ.

The first pair of pleuræ is the largest of the three pairs, both in breadth and length. Each pleura of this pair is composed of an inner attached and an outer free portion. This outer free portion consists of a long spine. The inner portion is at right angles to

<sup>1</sup> Salter, Pal. Soc. 'Mon. Brit. Trilobites,' p. 63, pl. vi. figs. 15, 16, & 17.

<sup>2</sup> *Ibid.* p. 73, pl. v. fig. 16.

<sup>3</sup> Törnquist, 'Undersökn. öfv. Siljans. Trilobitf.' Sver. geol. Undersökn. 1884, p. 12, pl. i. fig. 9.

<sup>4</sup> Angelin, 'Palæont. Scand.' 1854, p. 32, pl. xxi. fig. 3; Lindström, 'Förteckn. på Gotl. Silur. Crustac.' Öfv. k. sv. Vet.-Akad. Förhandl. 1885, no. 6, p. 45, pl. xiii. figs. 13 & 14.

the axis of the pygidium and extends to a prominent, triangular, articulating process which ends the narrow articulating band on the straight anterior edge of this portion. Beyond this articulating process the pleura becomes free and bends back at an angle of  $70^{\circ}$  to the anterior edge of the inner portion. This free or outer portion of the pleura is produced into a long flattened spine, part of which is broken off in our specimens. A strong oblique furrow traverses the inner portion of this pleura and is accompanied by a ridging-up of the surface on each side of it. Just before the pleura becomes free it attains its greatest width, which is equal to half the entire length of the pygidium itself. The outer or free portion tapers gradually backward and diverges from the second pleura at an angle of about  $50^{\circ}$ . The point at which this divergence commences is situated at the level of the anterior edge of the single, median, subterminal piece of the pygidium.

The pleuræ of the second segment are directed backward, and their free portions consist of spines running back parallel to the axis. The inner portion of each of these pleuræ has an anterior border slightly curved forwards and outwards, but the anterior, or rather outer, edge of the free portion is almost straight. The greatest width of this pleura is across the base of the free portion, as in the first pleura, but it does not amount to more than two-thirds of the greatest width of the first pleura. The spine of the second pleura, in addition to being more rounded and slender, cannot have been more than half as long as that of the first pleura. Neither the inner nor outer portion of the second pleura bears any furrow on its surface.

Each pleura of the third pair has its proximal or anterior portion only about one-third of the greatest width of the second pleura, with which it is in contact for the whole length of its proximal portion. These proximal portions of the third pair of pleuræ are directed backward and slightly inward, but nearly parallel to the axis of the pygidium and to each other. The flattened distal portions are not in contact with the second pleuræ, but bend sharply inward in close contact with the median posterior piece of the pygidium, and become nearly double the width of the proximal portions, to end each in a blunt point.

The median terminal, or rather subterminal, piece of the pygidium is triangular in shape and is completely embraced laterally and posteriorly by the third pair of pleuræ, so that the posterior end of the pygidium has a bifurcate appearance owing to the bluntly-pointed extremities of this pair of pleuræ. There is no furrow on the last pair of pleuræ or on the median subterminal piece.

The axis of the pygidium is triangular in shape, it tapers rather rapidly posteriorly, and its sides meet at the apex of the median subterminal piece at an angle of about  $60^{\circ}$ . The axis is very slightly convex and not much raised above the pleural portions of the pygidium. It is furnished with three rings, of which the first is rather broader than the posterior two, which are of equal breadth. Each ring is rounded and, owing to the extreme weakness and

shallowness of the axial furrows, appears to pass laterally into the pleuræ without any interruption. The furrows, however, separating the axial rings are well marked, but weaker in the middle than at the sides.

The median terminal piece has been described above.

The whole surface of the pygidium is ornamented with minute granulations.

*Affinities.*—The general appearance of the pygidium, particularly with regard to the characters and direction of the first and second pairs of pleuræ, reminds us considerably of *Ch. subulatus* (Linnarsson),<sup>1</sup> which occurs in the *Trinucleus*-schists of Western Gotland; but the bifurcated posterior extremity, owing to the projecting ends of the third pair of pleuræ, and the triangular instead of quadrate form of the median piece representing the fourth segment, are conspicuous differences. The point also at which the first and second pleuræ diverge from each other and become free spines is nearly equidistant from the anterior and posterior ends of the pygidium in our Keisley form, whereas in the Swedish species this point is on a level with the posterior end of the pygidium according to Linnarsson's figure. The pleuræ of the third segment in our form are also distinctly marked off from the axial portion by a transverse groove, whereas in *Ch. subulatus* there is no such separation.

The head-shields which I would tentatively ascribe to this species have been mostly assigned to *Ch. bimucronatus*, but they do not strictly agree with the typical form of that species nor with any of the hitherto recognized varieties. The resemblance between the pygidium of *Ch. keisleyensis* and *Ch. subulatus* has been noticed above, and when we compare the head-shield of Linnarsson's species with these of the so-called *Ch. bimucronatus* we cannot fail to remark the close similarity. The chief differences between the Swedish and Keisley forms are that in the latter the glabella is broader in proportion to its length, is more parallel-sided, and the eye is situated in a more forward position on the cheek.

From *Ch. bimucronatus* the Keisley form differs in the glabella being of a squarer shape and of greater width at the base, in the lateral furrows being straighter and not directed so much backward, and in the eye being placed a little in front of the second lateral furrow instead of slightly behind it.

Several hypostomes of a large *Cheirurus* have been found associated with the above-described species, though not in actual connexion or attachment. In point of size these hypostomes would just suit the head-shields of *Ch. keisleyensis*: they resemble very closely the hypostome of *Ch. bimucronatus* figured by Salter. The central convex portion has its sides a trifle more parallel, and the posterior end is rather broader and more obtuse, otherwise there is no apparent difference between the two.

Several disconnected thoracic segments belonging to large individuals of *Cheirurus* have been found. It is probable that they

<sup>1</sup> Linnarsson, 'Om Veetergötl. Cambr. och Silur. Aflagringar,' K. sv. Vet.-Akad. Handl. vol. viii. (1869) no. 2, pl. i. fig. 5, p. 60.

belong to *Ch. keisleyensis*, which is the common species, while *Ch. bimucronatus* is very rare. Their characters appear to exactly correspond with those of the latter species.

*CHEIRURUS* cf. *GLABER*, Angelin.

The single specimen in the Woodwardian Museum on which I rely for this determination bears an exceedingly close resemblance to Angelin's figure of *Cheirurus glaber*, Ang.,<sup>1</sup> and I do not think it justifiable to separate it without at any rate seeing Angelin's figured specimen. Schmidt<sup>2</sup> also describes and figures a species of *Cheirurus* which he compares with this species of Angelin's.

There are no important points of difference between our Keisley specimen and Angelin's species, as represented in his figure. The Russian individuals do not appear to resemble Angelin's species so closely. But in the presence of the pair of pits on the frontal lobe we see a point of similarity between the Russian and English individuals.

*Measurements.*

	millim.
Length of head-shield .....	23·0
"    glabella .....	16·5
Width of do. at base .....	13·0
"    "    across frontal lobes .....	16·5
Length of frontal lobe .....	8·5
Width of cheek (along posterior edge) .....	13·0
Distance of eye from axial furrow .....	4·0
"    "    "    posterior edge of cheek.....	6·0

*CHEIRURUS* cf. *CLAVIFRONS*, Dalm. ?

Portions of the glabella of a species of *Cheirurus* show a resemblance to *Ch. clavifrons*, but the fragmentary nature of our specimens renders any precise determination impossible.

*CHEIRURUS* (*PSEUDOSPHEREXCHUS*) *CONFORMIS*, Angelin.

Messrs. Marr and Nicholson<sup>3</sup> in 1888 recorded one species of this subgenus from the Stockdale Shales and named it *Ps. moroides*. Otherwise it has not previously been noticed in Britain. The species *Ch. (Ps.) conformis* is a characteristic form of the *Leptaena-Limestone* of Dalecarlia,<sup>4</sup> and its occurrence at Keisley is another important link in the chain of evidence connecting these two limestone patches.

Angelin<sup>5</sup> figures and describes the species, but imperfectly; however, Schmidt<sup>6</sup> gives a full description and excellent illustrations in

<sup>1</sup> Angelin, 'Palæont. Scand. 1854, pl. xxxix. fig. 16, p. 79.

<sup>2</sup> Fr. Schmidt, 'Rev. d. ostbalt. Silur. Trilob.' pt. i. p. 151, pl. vii. fig. 18 a & b, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. xxx. (1881) no. 1.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xlv. (1888) p. 722, pl. xvi. figs. 9, 10 & 10 a.

<sup>4</sup> Törnquist, 'Undersökn. öfv. Siljansområdets Trilobitfauna,' Sver. geol. Undersökn. 1884, p. 18, pl. i. fig. 12.

<sup>5</sup> Angelin, 'Palæont. Scand. 1854, p. 76, pl. xxxix. figs. 2, 2 a.

<sup>6</sup> Schmidt, 'Rev. d. ostbalt. Silur. Trilob.' pt. i. p. 174, pl. x. figs. 5, 6 7, 9, & pl. xvi. figs. 28-30, Mém. Acad. Imp. Sci. St. Pétersb. ser. 7, vol. xxx. (1881) no. 1.

his work on the East Baltic trilobites. Some of our specimens do not correspond with the type-form of the species, but more closely with the variety which Schmidt describes (*op. cit.* p. 176); and the very close relationship of the two species *Ps. hemicranium* (Kut.) and *Ps. conformis* (Ang.) var. of Schmidt is brought out by a minute comparison of them. Schmidt himself says that these two species of *Pseudosphærexochus* stand very close to each other, and the feature of the greater length of the glabella is almost lost in the variety from Borkholm.

In addition to several head-shields, a typical pygidium has been found at Keisley which measures nearly 2 millim. in length (excluding the spines), and 3·5 millim. in breadth.

It was from a pygidium similar in all respects to this one that Harkness recorded *Ch. octolobatus* from the Keisley Limestone.

**CHEIRURUS (PSEUDOSPHEREXOCHUS) SUBQUADRATUS, sp. n.** (Pl. XX. figs. 10 & 11.)

In addition to *Ch. (Ps.) conformis* (Ang.) in the Keisley Limestone, there occurs in greater abundance a form which must be considered very closely allied to Kutorga's species *Ch. (Ps.) hemicranium*, which has been described by various authors, and recently with minuteness by Schmidt.<sup>1</sup> The characters of the Keisley form are well marked and constant, but unfortunately only the head-shields are known. I hesitated for some time whether it could be satisfactorily separated from *Ch. (Ps.) hemicranium*, but with the advantage of more material for examination I am convinced that the new species rests on quite as firm a foundation as *Ch. (Ps.) conformis* (Ang.).

The description is as follows :—

The head-shield is almost semicircular in form, but the length is a little more than half the breadth. The glabella occupies more than one-third of its breadth and is rounded-subquadrate in shape; it is strongly convex and much elevated above the downwardly-sloping cheeks. The highest point of the glabella is situated about halfway along its length. The anterior part in front of the basal lobes is bent downward and more rounded and convex than the posterior part, which is slightly flattened. The length of the glabella is equal to the width, and the quadrate appearance is due to the width at the base being nearly as great as that across the middle, the axial furrows curving inward only very slightly behind the middle. The height is equal to about half the length. The frontal lobe is very short, being only about one-fourth the length of the glabella, owing to the forward position of the first lateral furrows. These furrows, which arise almost at right angles to the axial furrows and opposite the 'terminal pit,' are curved gently backward, and their free ends are separated by an interval at least twice as great as their length. They are only faintly marked and narrow.

<sup>1</sup> Schmidt, 'Rev. d. ostbalt. Silur. Trilob.' pt. i. p. 171, pl. x. figs. 1-4, & pl. xvi. figs. 22-27, *Mém. Acad. Imp. Sci. St. Pétersb.* ser. 7, vol. xxx. (1881) no. 1.

The second lateral furrow is situated halfway between the first and third lateral furrows. Like the first, it is curved gently backward and is faint and narrow. It does not exceed the first in length, and runs parallel to it.

The third side-furrow is much stronger and deeper, and curves more strongly backward towards the neck-furrow. It does not, however, reach the latter, and only a weak groove even in the casts appears to connect the two. The basal lateral lobes thus defined are rhomboidal in shape, do not rise above the general convexity of the glabella, and are separated by an interval equal to their own width.

The axial furrows are distinct and well marked, but not so broad as in *Ch. (Ps.) conformis*. The neck-furrow is stronger and broader than the axial furrows, and curves forward in the centre at the base of the glabella. The neck-segment is rounded, and has a width equal to about half the length of the basal lobes of the glabella.

The cheeks—the fixed portion is alone preserved in the Keisley specimens—bend down steeply on each side, with a convexity from back to front, and are scarcely at all elevated. The furrow marking off the neck-ring is distinct, and curves forward at the genal angle to pass into the broader marginal furrow. The genal angle is produced into a short, triangular spine, backwardly and slightly outwardly directed. The width of the cheek is considerably less than one-third of the total width of the head-shield, and this is a marked and important feature.

The anterior branch of the facial suture cuts the front margin of the head-shield nearly at the level of the first lateral furrow of the glabella, and thence runs backward parallel to the axial furrow of the eye. The posterior branch curves outward and backward from the eye, at first nearly parallel to the posterior margin, to cut the lateral margin a short distance in front of the base of the genal spine—nearly at the level of the third lateral furrow of the glabella.

The small eye is situated opposite to the second lateral lobe of the glabella, and approximately on the highest portion of the cheek. The eye-lobe rises up steeply from its base, and is there separated from the surface of the cheek by an oblique groove.

There is a broad and short 'frontal limb' in front of the glabella as figured by Schmidt (*op. cit.*) in *Ch. (Ps.) hemicranium*.

The whole surface of the head-shield is ornamented with small tubercles, not closely set, and the cheeks have in addition small pittings.

The points of difference between this form and *Ch. (Ps.) hemicranium* are: (1) the greater breadth of the glabella in proportion to the head-shield; (2) the smaller breadth of the head-shield; (3) the subquadrate shape and greater convexity of the glabella; (4) the more forward position of the point of section of the lateral margin by the facial suture. In all other points the two species seem to agree very closely.

In size the Keisley form is about double that of any of the Russian specimens of *Ch. (Ps.) hemicranium*. One of our head-shields of

*Ch. (Ps.) subquadratus* measures 17 millim. in length and 32 millim. in width; the glabella of this specimen measures nearly 15 millim. in length, and the breadth is the same across the middle and 13 millim. at the base. The largest specimen that I have seen has a head-shield 23·5 millim. in length, but most of them range between 16 and 18 millim.

*Note.*—A hypostome found unconnected with any head-shield shows some new features, though on the whole it resembles that of *Ch. (Ps.) hemicranium* figured by Schmidt. It may therefore not improbably belong to this new species *Ch. (Ps.) subquadratus*. In shape it is broadly ovate, obtusely pointed behind and rounded in front. The central area, which is slightly but regularly convex, has parallel sides and a truncated front end. A rather deep furrow surrounds this area and marks off a tumid border with an average width of about one-sixth of the central area. This border is thickened and more elevated at the posterior end of the hypostome, but at the anterior end it is indented by a deep notch on each side, and produced into a tapering 'ascending process' with a broad base as in typical species of *Cheirurus*. The whole surface of the hypostome is granulated, and on the convex central area are also some scattered pits. The length of the hypostome is 8·5 millim., and the breadth 7 millim. across the middle.

#### *SPHÆROCORYPHE GRANULATA*, Angelin?

A small globular glabella showing a little nodular lobe at the base and a portion of the fixed cheek corresponds, so far as these fragmentary portions permit determination, with Angelin's species *Sph. granulata*.<sup>1</sup> The ornamentation of the surface is also similar.

#### *SPHÆREXOCHUS MIRUS*, Beyr.

There occur in the Keisley Limestone numerous heads exactly like those of this well-known trilobite. I have seen only one typical pygidium from this bed, and it is quite probable that some of the heads belong to the species I have called *Sph. latirugatus*, for the pygidia of this latter species are associated with the heads of the so-called *Sph. mirus*. I am unable to make two species out of the head-shields, though variations in the distance apart of the basal lobes, etc., do occur, as Salter himself has remarked.

#### *SPHÆREXOCHUS LATIRUGATUS*, sp. n. (Pl. XX. fig. 12.)

A pygidium has recently been found which, while undoubtedly belonging to the genus *Sphærexochus*, presents many points of difference from the common British species *Sph. mirus*. It resembles Lindström's<sup>2</sup> *Sph. laciniatus* more closely than any other species

<sup>1</sup> Angelin, 'Palæont. Scand.' 1854, p. 76, pl. xxxix. fig. 4; Schmidt, 'Rev. d. ostbalt. Silur. Trilob.' pt. i. pl. viii. figs. 17-19, p. 169, Mém. Acad. Imp. Sci. St. Pétersb. ser. 7, vol. xxx. (1881) no. 1.

<sup>2</sup> Lindström, 'Förteckn. på Gotl. Silur. Crustac.' Öfr. k. sv. Vet.-Akad. Förhandl. 1885, no. 6, p. 47, pl. xiii. fig. 6.

that I know, particularly in the raised ridge-like ribs, the wide interpleural grooves, and the elongated axis.

The Keisley pygidium is about twice as wide as it is long. The axis is less than one-third the width of the pygidium at its anterior end, and is triangular in shape. It is convex and more elevated than the lateral lobes, but decreases in height posteriorly. Its length is twice as great as its width at its anterior end. It is composed of three segments: the first two form two prominent rounded rings, separated by a wide deep groove; the third segment is marked off from the second by a somewhat wider groove of the same depth, and consists of an elongated triangular piece with a pointed posterior end and sides converging at an angle of about  $50^{\circ}$ . It is as long as the whole anterior part of the axis, and its pointed extremity just touches the concave posterior margin of the pygidium between the third pair of ribs.

The axial furrows are not deep, but are distinct, particularly along the sides of the terminal segment.

The lateral lobes are almost flat and horizontally extended; they are rudely triangular in shape, and have the margins scalloped owing to the projection of the rib-ends. The anterior edge is not so strongly curved back as in *Sph. laciniatus* (Lindstr.), nor is the fulcrum so distinct, but the edge is similarly formed by the rounded prominent first rib, which is continued with equal strength to the lateral angle at which it projects with a rounded extremity. The second rib, corresponding to the second axial ring, forms a similar prominent rounded ridge on the lateral lobe, but curves backward rather more strongly and increases slightly in width. It projects, like the first rib, beyond the pygidial margin.

The wide, shallow, concave depression separating it from the first rib is more than twice as wide as the ribs themselves on the margin. Owing to the projection of the extremities of the first and second ribs, the margin makes a re-entrant angle between them.

The third pair of ribs are almost parallel to each other, and run straight backwards as low rounded ridges expanding posteriorly. They start from the anterior end of the terminal axial segment, and form rounded projections on the posterior margin of the pygidium. They are separated from the second pair of ribs by a wide shallow groove, rather wider than the ribs themselves, and from the terminal axial segment by a similar groove of rather less width.

The pygidial margin between the extremities of the second and third pairs of ribs forms a wide rounded re-entrant angle, and between the ends of the third pair of ribs themselves a slight re-entrant curve. In *Sph. laciniatus* this curve is much narrower and stronger.

It is probable, as mentioned above, that some of the head-shields called *Sph. mirus* in the Keisley Limestone belong to this new species, but, in the absence of any distinct features by which to separate them, it is impossible to be certain. The exact agreement, so far as I can see, of the head-shields with those of *Sph. mirus* makes one suspect that the specific difference may be capable of detection only in the pygidia.



It is, however, impossible to express a decided opinion until we find indubitable evidence that some of the so-called *Sph. mirus*-heads of the Keisley Limestone belong to the new species *latirugatus*.

It is noteworthy in this connexion that only one typical *Sph. mirus*-pygidium has been found at Keisley, whereas fragments of the *Sph. latirugatus*-pygidium are not very uncommon.

	millim.
Length of pygidium .....	8
Breadth           ,,           .....	15

Some other less perfect specimens must have been longer in proportion to their breadth.

*Note*.—Salter (Geol. Surv. dec. vii. 1853, pl. iii. fig. 15) figures a tail of this new species from Kildare, but includes it with *Sph. mirus*, though with the remark that it is 'more elongated than in the Dudley specimens.' I have seen several specimens from Kildare agreeing with the above description.

#### STAUROCEPHALUS MURCHISONI, Barr.

This genus has not previously been recorded from the Keisley Limestone, but I was fortunate enough to obtain more than half a dozen specimens of the head-shield during a recent visit. They occurred in the same blocks with many of the characteristic Keisley Limestone fossils, so that no doubt can be entertained that they belong to this horizon.

Their identification with Barrande's species is rendered specially easy, since in the Woodwardian Museum is a head of *Staurocephalus* from Rhiwlas (figured by M'Coy) which Barrande himself examined and held was indistinguishable from his Bohemian species.<sup>1</sup> Our Keisley specimens show all the typical features, though unluckily the free cheeks are not preserved. The position of the eye at once distinguishes this species from *St. globiceps* (Portl.), figured and described carefully by Salter.<sup>2</sup>

#### ACIDASPIDÆ.

##### ACIDASPIS CONVEXA, sp. n. (Pl. XXI. fig. 6.)

The genus *Acidaspis* has not previously been recorded from the Keisley Limestone, but I have recently found two fairly good head-shields presenting characters which prove that they belong to this genus, and to a new species.

The head-shield of this new form is very convex from back to front, and also, but to a less extent, from side to side. The glabella shows a median convex portion of cylindrical shape, with parallel sides and more than twice as long as wide. This central portion of the glabella forms the crest of the head-shield, and its apex is nearer the front than the hind border. The anterior end is lofty, steep, and abrupt, but the posterior end slopes more gradually down to the

<sup>1</sup> It is mentioned by Barrande in 'Syst. Sil. Bohême,' vol. i. (1852) p. 812, pl. xliii. fig. 28.

<sup>2</sup> Mem. Geol. Surv. dec. xi. (1864) pl. v. fig. 6, p. 3.

level of the less elevated neck-ring. There are two distinct pairs of lateral lobes of very unequal size. Each of the lobes of the basal pair is elliptical in shape, obliquely directed forward and outward, and is separated from the median portion of the glabella by a strong furrow. The middle pair of lateral lobes consists merely of two small circular nodules situated rather more than halfway forward towards the front end of the glabella. There are slight indications of a first pair of lateral lobes.

The inner portion of each fixed cheek rises into a semilunar rounded ridge embracing the side of the basal and middle lobes of the glabella, but not elevated to more than half the height of the basal lobes and separated from them by the curved axial furrow. At the posterior end of this rounded ridge, and slightly towards its outer side, is a small oval nodule. The outer portion of the fixed cheek is small and apparently flat, with its posterior margin curving backward. The facial suture runs backward and obliquely outward to the small rounded eye-lobe, and thence in the same direction to the posterior margin of the head-shield so as to cut it at an angle of about  $45^{\circ}$ . The eye is situated rather behind the middle of the glabella, at the end of a low ridge which traverses the flat outer portion of the fixed cheek with a slightly oblique course.

At the base of the axial furrow on each side of the distinct neck-furrow is a small rounded nodule lying behind the basal lobes of the glabella. The neck-ring is rounded and rather wide for the size of the head-shield, but apparently is not provided with an axial spine. A narrow neck-segment is discernible behind the fixed cheek, and by its backward curvature seems to indicate that the genal angles were furnished with spines. The surface of the head-shield is finely tuberculated. The free cheeks are unknown.

	millim.
Length of middle shield .....	3.0
Width of do. at base .....	5.0
Greatest height (close to anterior end of glabella) .....	2.0
Length of glabella .....	2.0
Width of do. at base .....	1.5

Barrande's species, *Acidaspis minuta*, from Étage E bears a close resemblance to this Keisley form, but in the Bohemian species the middle lateral lobes of the glabella are oval and much larger, and are situated nearer the anterior end of the glabella. The species described by Törnquist<sup>1</sup> as *A. evoluta* from the *Leptæna*-Limestone is closely allied, but it differs in the larger size of the second lateral lobe, and the greater width of the glabella. The outer portion of the fixed cheek and facial suture are moreover not figured.

#### ACIDASPIS, sp.

A fragment of the head-shield of an *Acidaspis* in the Carlisle Museum shows some peculiar features, but it is not sufficiently well preserved to enable us to assign it to any known species or to

<sup>1</sup> Törnquist, 'Undersökn. öfv. Siljans. Trilob.' Sver. geol. Undersökn. 1884, p. 28, pl. i. fig. 24.

describe it as a new one. The base of a parallel-sided cylindrical glabella is seen with a pair of very narrow elongated basal lobes pressed close against its sides. These lobes do not measure in width more than one-third of the width of the glabella. Outside each of these lobes is a broader, rounded, swollen ridge, running forward and curving slightly inward. At the base of the axial furrow which separates this ridge and the basal lobe is a deep pit. The narrow neck-lobe at the base of the glabella is furnished with a very strong central tubercle.

	millim.
Length .....	2.5
Breadth.....	4.0

#### LICHADÆ.

##### LICHAS LAXATUS, M'Coy.

One extremely sharp cast of the pygidium of this well-known species shows all the typical features, which need no description.

##### LICHAS AFFINIS, Angelin.

The occurrence of this characteristic species of the *Leptæna*-Limestone in the Keisley Limestone is established not only on the evidence of a head-shield, but also on that of several pygidia, of which one, fairly well preserved, is in the Woodwardian Museum. Angelin's<sup>1</sup> original figures and description were inadequate and unsatisfactory, but by means of Törnquist's<sup>2</sup> more recent diagnosis and illustrations, and by comparison with actual Dalecarlian specimens, I have no doubt of the correct identification of the English individuals.

#### Measurements.

	millim.
Length of median lobe of glabella .....	15.0
Width of do. across anterior end.....	16.0
Width of do. at the level of the posterior end of the first side-lobes.....	6.0
Length of first side-lobe .....	10.0
Width of do. ....	6.0
Length of pygidium (so far as preserved) .....	24.0
Estimated length of do. when perfect.....	38.0
Width of do. along anterior edge .....	41.0
Width of do. at level of axial knob .....	44.0
Width of axis at anterior end .....	13.0
Width of do. at end of axial furrows .....	6.5
Length of do. to end of axial furrows .....	13.0
Greatest width of post-axal area .....	11.0

##### LICHAS CONFORMIS, Ang., var. KEISLEYENSIS, nov. (Pl. XXI. fig. 10.)

For the determination of this species we have again to rely upon a single imperfect specimen of a pygidium and on Angelin's figure and brief description.<sup>3</sup> Since the Swedish and Keisley forms agree

<sup>1</sup> Angelin, 'Palæont. Scandín.' 1854, pl. xxxviii. fig. 4, p. 69.

<sup>2</sup> Törnquist, 'Undersökn. öfv. Siljans. Trilob.' Sver. geol. Undersökn. 1884, pl. i. fig. 31, p. 33.

<sup>3</sup> Angelin, *op. supra cit.* pl. xxxviii. fig. 5, p. 74.

completely, except in three trifling details, there is not sufficient reason to institute a new species. The three points of difference are: (1) the point of origin of the oblique furrow on the second pleura; (2) the length of the axial furrows; and (3) the more abrupt posterior truncation of the axis in the British form. But I do not consider these differences to be of more than varietal importance.

The axial furrows are fairly well marked on each side of the axis, though at its posterior end they curve inwards, become less distinct, and do not quite meet in the centre, thus leaving the axis at its apex undefined and continuous with the post-axal area. In Angelin's figure of *L. conformis* the axial furrows pass over completely into the furrows marking out the sides of the post-axal area, and do not bend inwards round the extremity of the axis.

In the case of the second pleura a furrow traverses the pleural surface parallel (for the greater part of its length) to the hind border, but dies out before reaching the free point of the pleura. In Angelin's *L. conformis* the pleural furrow has a more central position on the surface, and originates at the middle point of the base.

#### Measurements.

	millim.
Length of pygidium .....	24
Greatest width of do. at level of proximal end of second interpleural furrow .....	31
Length of axis .....	10
Width of anterior end of do. ....	10
Length of post-axal area .....	14
Width of anterior end of do. ....	7
Width of middle of do. ....	5

#### LICHAS HIBERNICUS, Portl.

The occurrence of this species in the Keisley Limestone is another proof of the close affinity of its fauna with that of the Kildare 'Bala' Limestone. A glabella with the median and large lateral lobe well preserved has been found at Keisley. It exhibits the typical characters of the species. So far as one can judge from Schmidt's<sup>1</sup> figures and descriptions, there is every reason to consider his *L. Holmi* identical with Portlock's species.

#### LICHAS BULBICEPS, Phill. MS. (Pl. XXI. figs. 8, 8a, 8b & 9.)

This species is represented in the Woodwardian Museum by a very perfect middle shield and by a fragment of another.

The middle shield is strongly convex in an antero-posterior direction, the anterior half curving down steeply in front to the margin. From side to side across its middle the convexity is slight, but uniform; the posterior half is flattened. The outline of the anterior margin of the head-shield is semicircular.

The glabella has all its lobes well developed. The frontal

<sup>1</sup> Mém. Acad. Imp. Sci. St. Pétersb. ser. 7, vol. xxxiii. (1885) no. 1: 'Rev. ostbalt. Tril.' pt. ii. p. 54, pl. vi. figs. 14 & 15.

(= median) and anterior side-lobes each have a gentle independent convexity of their own, but are somewhat flattened towards their posterior ends. The middle and posterior side-lobes are flattened, and do not rise above the common flattened surface of the posterior half of the glabella. The cheeks curve down on each side with a slight convexity of their own.

A front view of the head-shield shows a gentle median upward curve in the anterior edge forming a shallow bay, as in *L. verrucosus*, Eichw. A narrow rounded border runs round the anterior margin and is separated from the glabella by a shallow marginal furrow passing laterally into the axial furrows. The latter, and all the glabellar furrows, are well marked and of equal depth.

The anterior glabellar side-furrows curve at first strongly inward, but then run backward with a convergence of about  $30^\circ$  for more than two-thirds the length of the glabella; then they bend sharply outward and forward at an angle of  $60^\circ$  to their former course to form the incomplete middle side-furrows. These middle side-furrows become suddenly faint about the middle of the base of the anterior glabellar side-lobes, but are traceable into the axial furrows. The posterior side-furrows are short and straight, and form the direct lateral continuation of the straight median portion of the neck-furrow, so that the glabella here appears crossed by a single straight horizontal furrow, as in *L. verrucosus*, Eichw. This horizontal furrow meets the axial furrows at right angles. The neck-furrow on each side of the point of union with the posterior side-furrows of the glabella bends sharply backward, so as to define the basal glabellar lobe.

The axial furrows start from the point of junction of the marginal and anterior side-furrows, and a small pit is here situated. From this pit the axial furrows run backward, curving outward in a convex bow at the point where the 'eye-furrow' branches off. Thence they curve inward with an uniform gentle concavity, and thus reach the neck-furrow; but opposite the middle and basal glabellar lobes their curve is slightly distorted and pushed outward.

The frontal or median lobe of the glabella, from its front end to the level of the middle side-furrow, reaches over two-thirds the length of the head-shield. It has a marked convexity of its own, particularly strong in its front part. The anterior downward slope of its front end commences about halfway between the neck-furrow and the anterior margin. The width of its front end is nearly three times as great as the width of its posterior end at the level of the middle side-furrows. The anterior lateral angles of this median or frontal lobe are bluntly pointed, and overhang the anterior side-lobes to half their width.

The anterior side-lobes are roughly elliptical in shape, but their ends are somewhat pointed. The middle side-lobes have a sub-quadrate appearance, owing to their posterior outer angle being a right angle and the third side-furrow being straight. They are not marked off from the middle portion of the glabella either by a furrow or by possessing an independent convexity. They are



*Affinities.*—The Keisley species *L. bulbiceps* resembles *L. verrucosus*, Eichw., in the general arrangement and relations of the different lobes and furrows, but it differs (1) by having a relatively much shorter head-shield; (2) by possessing a much greater convexity than that species; (3) by the flattening of the posterior portion of the middle shield; (4) by the larger size and triangular, instead of elliptical, shape of the basal lobes of the glabella; (5) by the angle of convergence of the anterior side-furrows of the glabella; (6) by the concave curvature and greater length of the axial furrows between the middle side-furrow of the glabella and the neck-furrow.

*Note.*—A hypostome of a *Lichas* with many points of resemblance to the hypostome of *L. verrucosus* probably belongs to *L. bulbiceps*. It is subquadrate in general outline, and is nearly as broad as it is long. It consists of a median swollen rounded portion, subcircular in outline and sharply marked off by a deep furrow from the border above which it is raised. It is notched near its posterior end by a pair of short, deep, oblique lateral furrows which are directed backwards. Its surface is ornamented with small but distinct tubercles of equal size, arranged with some degree of regularity. The border surrounding this central portion is very narrow in front, but expands at the anterior lateral angles into short, bluntly pointed 'anterior wings,' behind which the sides of the hypostome run back parallel to each other. The border increases in width, and has its edge slightly turned up and rounded as far as the posterior end of the median portion, behind which it expands and has its edge bent downward. This hinder portion of the border is ornamented with a series of striae parallel to the lateral margin. The posterior side of the hypostome is excavated so as to appear forked, and immediately behind the median portion the border attains its greatest width, and is raised into a low prominence. The length of the hypostome is a little over 6 millim.

*LICHAS BIFURCATUS*, sp. n. (Pl. XXI. fig. 7.)

It seems inadvisable to regard the pygidium on which this species is founded as belonging to *L. bulbiceps*, for no species allied to the latter has a pygidium with such characters. The pygidia rather of such species as *L. triconica* (Dames) and *L. margaritifer* (Nieszk.), with their forked extremity, approach most closely to it.

Our pygidium is about one and a half times as broad as long; its shape is almost parabolic, but it is pointed and forked posteriorly.

The axis occupies the middle third of the width of the pygidium and extends for nearly half its length. It is strongly convex, and tapers gradually to its posterior end, which is truncate, abrupt, and steep. The articulating ring on the front end is broken off, but there are three rings crossing the axis, the first of which is strong, narrower at the middle than at the sides, and marked off by deep wide furrows behind and before. The second ring is very similar to the first, and the third, which is of more uniform width, is defined posteriorly only by a faint furrow.

The lateral portions of the pygidium are flat and horizontally extended in one plane. All the furrows are of equal strength. The anterior pair of pleuræ is very imperfectly preserved; only the base is visible, but this part is seen to be equal in width to the first two axial rings. The diagonal furrow across its surface starts from nearly the middle of the base. From comparison with allied forms it is probable that this first pleura ended on the margin in a short, backwardly-directed, free point.

The second pleura has the same basal width as the first, but its posterior limiting-furrow starts behind the faint posterior limiting-furrow of the third axial ring. This pleura expands in width in the middle, and then contracts to end in a very short recurved point which scarcely projects beyond the margin. The posterior limiting-furrow of this pleura runs in a straight line to the pygidial margin at an angle of about  $45^\circ$  to the median line of the axis. The furrow traversing the surface of this pleura starts from the anterior angle of the base and runs parallel to the posterior edge of the pleura, but bends round sharply at its outer end to reach the recurved point.

The third pleura is almost a right-angled triangle, the hypotenuse being the posterior or rather inner limiting-furrow, which is a continuation of the axial furrow. The free terminations of this third pair of pleuræ form the short approximate points of the posterior end of the pygidium, which give it its forked appearance. The surface of each pleura of this pair is crossed by a furrow which, starting from about the middle point of the base, runs backward nearly parallel to its fellow and to the median line of the axis, but with a very slight outward curvature. After traversing more than three-fourths of the pleura it becomes faint, and curves round rapidly inward to join the posterior limiting-furrow, thus circumscribing with the latter a lanceolate area, as in *L. laxatus* and others.

The axial furrows are distinct, and are continued directly into the posterior limiting-furrows of the third pair of pleuræ. These latter furrows are straight, and converge posteriorly at an angle of  $20^\circ$  for more than three-fourths of their length—*i. e.* to the point where the diagonal furrow of the third pleuræ joins them. Behind this point they become fainter and converge twice as rapidly as before to meet each other at the fork between the free ends of the last pair of pleuræ. The flat post-axal area between them has therefore a tapering and peculiar shape.

The whole surface of the pygidium is covered with tubercles of medium size, with smaller ones interspersed.

#### *Measurements.*

	millim.
Length of pygidium .....	9.0
"    axis .....	4.0
Width of do. at front end .....	4.5



*Affinities.*—The pygidium of *L. margaritifer* (Nieszk.)<sup>1</sup> very closely resembles the one above described. The forked extremity, the three rings on the axis, the course of the axial furrows with their ends bending out to define the lanceolate areas on each side of the post-axal area, the projection and shape of the two anterior pairs of pleuræ, and the general form of the pygidium are points of similarity. The most conspicuous point of difference is the continuation of the axial furrows to the fork, which gives a very marked appearance to this portion of the pygidium in the Keisley form, and is in my opinion sufficient to separate it off as a distinct, though allied, species.

*L. margaritifer* occurs in the Borkholm Beds (F2) in East Russia, and the occurrence of this English representative form *L. bifurcatus* in the Keisley Limestone is another link between the faunas of the two beds.

#### PROETIDÆ.

CYPHASPIS (TÖRNQUISTIA, subgen. nov.) NICHOLSONI, sp. n. (Pl. XXI. figs. 3 & 3 a.)

There are four specimens of this new form in the Woodwardian Museum Collection,<sup>2</sup> but in three cases the central portion only of the head-shield is preserved, while in the fourth case the head-shield has one free cheek attached, though slightly shifted out of its natural position.

The description of this species is as follows:—Head-shield nearly semicircular, gently convex, 3 millim. long. Glabella broadly ovoid, slightly and gradually narrowing towards the rounded anterior end. Width at base nearly equal to length. Length equals about three-fifths that of the head-shield. Glabella uniformly semicylindrical in shape, rounded off in front.

The base of the glabella occupies nearly one-third of the distance between the points where facial sutures cut the hinder border of the head-shield. The glabella possesses no basal lobes nor side-furrows.

Axal furrows well marked, of constant depth and width, uniting in front of the glabella, where at the median point of union a short groove runs forward notching posteriorly the convex frontal area, but not traversing it. At the antero-lateral angles of the glabella, where the axal furrows curve inward round its front, there is on each side a similar but longer groove running outward and slightly forward over the swollen fixed cheek to the line of the facial suture, and separating the frontal area from the fixed cheeks proper. This triradiate group of grooves is a conspicuous feature of the head-shield.

Neck-furrow well marked, of the same width and depth as the axal furrows. The neck-lobe measures from back to front, across its middle, about a quarter the length of the glabella, but does not rise to more than half the height of the latter. Behind the fixed

<sup>1</sup> Nieszkowski, 'Monogr. d. Trilob. d. Ostseeprov.' Archiv f. Naturk. Liv. Est. u. Kurl. ser. 1, p. 568, pl. i. fig. 15.

<sup>2</sup> There is another specimen (labelled *Agnostus*) in the Carlisle Museum.

cheeks the neck-segment diminishes to about one-half the breadth and height of the neck-lobe. The fixed cheeks are produced as regularly swollen 'anterior wings,' on each side of the glabella, and these wings are about as wide as the glabella. In front of the glabella they unite and constitute the convex frontal area, which is as high as the 'anterior wings' but wider, and has, like them, a steep inner or posterior, but gentler anterior or outer slope.

The facial sutures cut the front margin of the head-shield at a distance one from another equal to about  $1\frac{3}{4}$  times the basal width of the glabella. Each runs at first backward and slightly inward to the antero-lateral groove, which separates the frontal area from the anterior wing of the fixed cheek; then it takes a slight outward trend to the eye-lobe, which is very indistinct in our specimens; from this point it makes a sudden bend outward so as to become nearly parallel to the hind border of the head-shield, finally bending sharply backward to cut the margin.

What appears to be the free cheek (badly preserved) is triangular in shape and not swollen; it bears a large, smooth, ovate eye, which lies a little behind the middle of the glabella and at the sharp re-entrant angle of the facial suture. The genal angle appears to have been produced into a spine.

The front and sides of the head-shield are surrounded by a narrow, smooth, raised, rounded border, separated from the frontal area and free cheeks by a marginal furrow, which is nearly as wide as the axial furrows.

The whole surface of the head-shield is covered with fine granulations and scattered tubercles of various sizes without any definite arrangement, but the middle point of the neck-lobe of the glabella is generally marked by a specially large isolated tubercle.

The thorax and pygidium are unknown.

*Affinities.*—The close resemblance to Törnquist's *Trilobites triradiatus*<sup>1</sup> which our Keisley form bears led Messrs. Marr and Nicholson<sup>2</sup> to compare it with that species; but on a minute examination of our specimens by the side of Törnquist's figure and description, I am convinced that they must be considered distinct. The shorter length, more rounded and ovoid outline, and greater width of the glabella; the absence of the pair of notches or short furrows at its base; the non-continuation of the median notch as a groove over the frontal area; and the more rounded and swollen character of the anterior wing of the fixed cheek, are the chief reasons which lead me to this conclusion.

Törnquist's species and ours are, however, very closely allied, and present in common important features, which mark them off from a typical *Cyphaspis*, namely, (1) the absence of the basal lobes to the glabella; (2) the presence of the three radiating notches or grooves at the front end of the glabella.

<sup>1</sup> Törnquist, 'Undersökn. öfv. Siljans. Trilob.' *Sver. geol. Undersökn.* pl. iii. fig. 18, p. 92.

<sup>2</sup> Marr & Nicholson, 'The Cross Fell Inlier,' *Quart. Journ. Geol. Soc.* vol. xlvii. (1891) p. 507.

These characters necessitate, in my opinion, the creation of a subgenus of *Cyphaspis*, which may appropriately be termed *Törnquistia*. Our Keisley form may aptly bear the specific name *Nicholsoni*, in honour of its discoverer, Prof. H. A. Nicholson.

*CYPHASPIS*? *HARKNESSI*, sp. n. (Pl. XXI. fig. 2.)

Glabella conical, gently convex, elevated above cheeks, tapering gradually towards its rounded anterior end, which apparently reaches the front margin of the head-shield. A pair of incompletely defined basal lobes is present. No other lobes or traces of furrows on the glabella. The furrow which partially defines the inner side of each basal lobe runs from the neck-furrow forward and inward for a short distance as a faint groove, making an angle of about  $60^\circ$  with the neck-furrow; then it suddenly bends round at a right angle to its previous course, and runs in a straight line outward and forward with increased strength, to end abruptly in a sort of pit before reaching the axial furrow. There is a similar expansion and depression at the bend in its course. The basal lobes thus marked off are subcircular in shape, nearly half as long as the glabella, and about one-third of its basal width, gently convex, but not rising above the rest of the glabella, though projecting slightly on each side of it. Axal furrows distinct, but not deep. Neck-lobe of medium width, separated from the glabella by a very strong neck-furrow. Posterior part of fixed cheek triangular in shape, flattened, and gently bent downward; anterior wing imperfect, apparently of similar shape, but smaller. The facial suture cuts the posterior border of the head-shield at a distance from the axial furrow of less than half the basal width of the glabella; thence it runs forward and inward with a gentle curvature towards the anterior end of the basal lobe of the glabella. At this point, where the eye was situated, it appears to curve away from the glabella with the concavity of the curve forward, and cuts the front margin at some distance from the axial furrow. Outline of head-shield only partially preserved, probably semicircular; narrow rounded border visible. Whole surface of head covered with tubercles of various sizes.

*Measurements.*

	millim.
Length of head-shield .....	12.5
"    of glabella .....	10.0
Width of do. at base .....	12.0
"    at anterior end .....	9.0
Length of basal lobes of do.....	4.5

*PHILLIPSINELLA PARABOLA*, Barr.

Two glabellas of this species, with portions of the fixed cheeks attached, have been found. There are also in the Woodwardian Museum two pygidia, which correspond very closely with those ascribed to this trilobite by Linnarsson, who called it *Phillipsia*.<sup>1</sup>

<sup>1</sup> Linnarsson, 'Om Vestergötl. Cambr. och Silur. Aflagr.', K. svensk. Vet.-Akad. Handl. vol. viii. (1869) no. 2, p. 72, pl. ii. fig. 32.

This species has been recorded from the Haverfordwest area by Messrs. Marr and Roberts,<sup>1</sup> but this is the only mention of its occurrence in Britain, so far as I am aware.

#### HARPEDIDÆ.

##### HARPES WEGELINI, Ang.

Fragments of the head-shield of this large species are not very uncommon in the Keisley Limestone, but I have not seen a glabella. In all points the limb and genal portion with the narrow border surrounding the head-shield agree with Angelin's figures, and with specimens from the *Leptaena*-Limestone with which I have been able to compare them.

##### HARPES COSTATUS, Ang. ?

A portion of a head-shield of a *Harpes* appears to belong to this species of Angelin,<sup>2</sup> for it shows the convex perforated limb, the narrow striated border, and the convex genal portion with the prominent eye-tubercle; but the glabella and other parts are not preserved. Angelin's species occurs in the *Leptaena*-Limestone.

##### HARPES, sp. α. (Pl. XXI. fig. 4.)

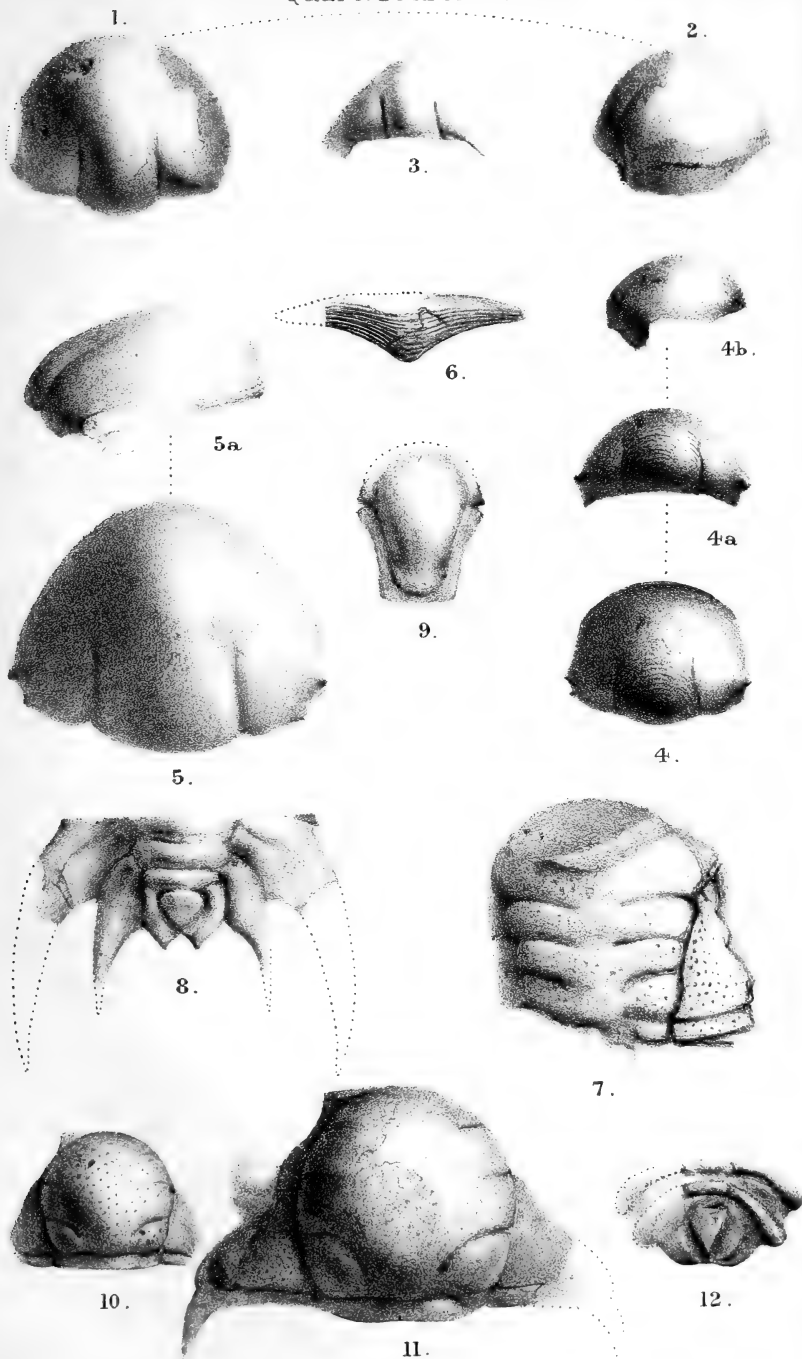
The posterior end of a very small trilobite consisting of a minute pygidium with several thoracic segments attached, has recently been found, and must be held to belong to the genus *Harpes*. The portion preserved is in all only 2 millim. long, and a little over 4 millim. broad. The thoracic portion consists of horizontally-extended pleuræ in close contact with each other, and of a raised convex axis. The pleuræ are narrow, flat, and rectilinear, with parallel borders, and without any visible furrow. There is no break between the thoracic and the pygidial portions of the specimen. The pygidium is transversely elliptical in shape, and has a straight front edge and slightly rounded angles. Its axis is very narrow, being only about one-fifth of the whole width of the pygidium at its anterior end; it tapers very gradually posteriorly, but is short, and does not reach the posterior margin. There are two or three very faint rings on it, and just traces of ribs on the lateral lobes.

##### HARPES, sp. β. (Pl. XXI. fig. 5.)

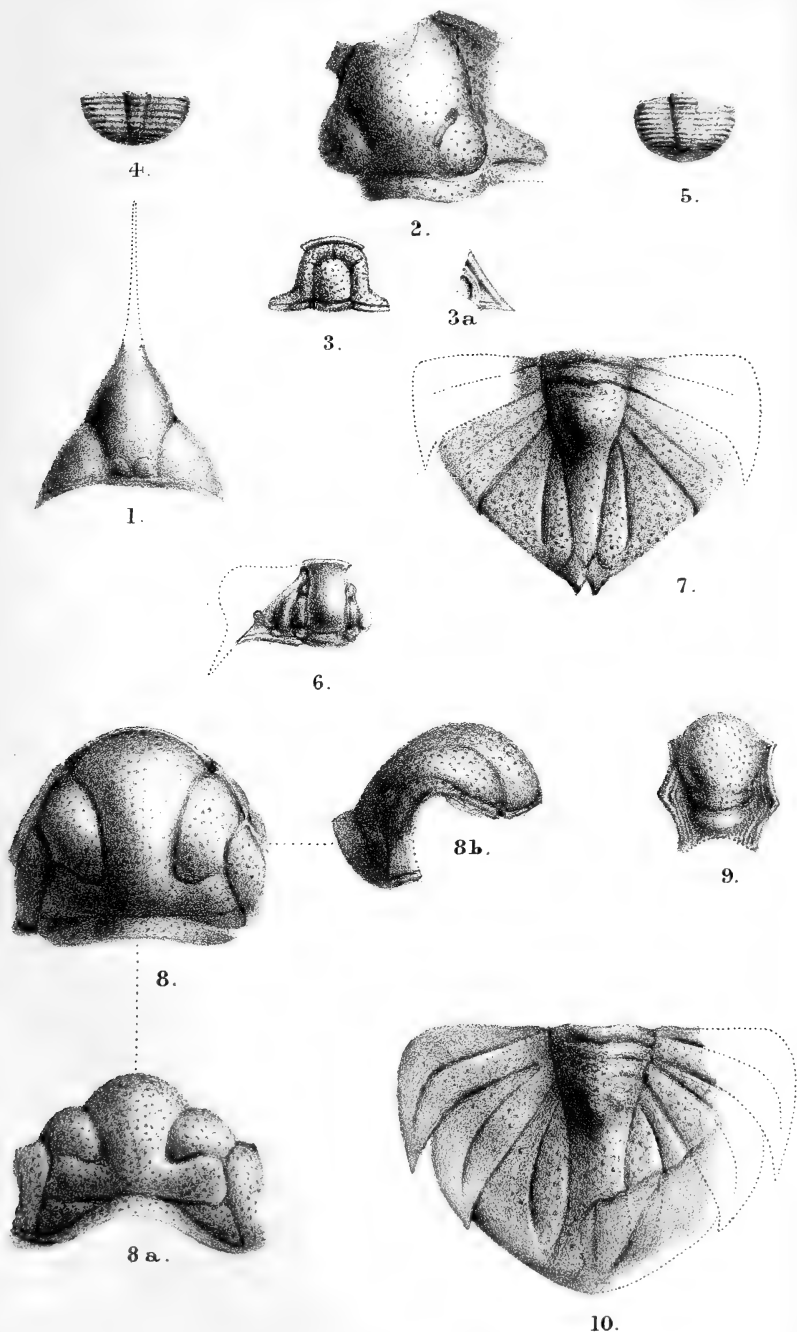
Another pygidium of a *Harpes* of about the same size has been found, with several body-rings attached. It resembles the one above described in the character of the rectilinear pleuræ, the flat horizontal lateral lobes of the pygidium, and the absence of any furrow on the ribs; but it differs in the relatively broader axis and its more rapid tapering, so that it terminates some distance from the margin. The anterior end of the axis is nearly one-third the width of the pygidium. At first sight it is almost impossible to say where the thorax ends and the pygidium begins, for there is no marked break in the series of eight or nine rings on the axial portion, nor

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xli. (1885) p. 476.

<sup>2</sup> Angelin, 'Palæont. Scand. 1854, p. 85, pl. xli. fig. 4.







F.H. Michael del. et lith.

TRILOBITES FROM THE  
KEISLEY LIMESTONE.

Mintern Bros. imp.





between the five or six pleuræ. By careful inspection, however, it is seen that a terminal portion, consisting of two or three segments, is bent down rather more sharply than the rest, as if composed of one piece. This is the pygidium, with a very short axis—about one half its entire length—crossed by two or three faint rings. The breadth of the pygidium is about three times as great as the length.

## EXPLANATION OF PLATES XX. &amp; XXI.

## PLATE XX.

- Fig. 1. *Illænus galeatus*, sp. n. From above. Natural size.  
 2. Do. From the side. Natural size.  
 3. Do. Another specimen. From behind. Natural size.  
 4. *Illænus Bowmani*, var. *brevicapitatus*. Natural size.  
 5. *I. Bowmani*, var. *longicapitatus*. Natural size.  
 6. *Illænus*, sp. Hypostome. Natural size.  
 7. *Cheirurus keisleyensis*, sp. n. Natural size.  
 8. Do. Pygidium. Natural size.  
 9. Do. Hypostome. Natural size.  
 10. *Ch. (Pseudosphærexochus) subquadratus*, sp. n. Natural size.  
 11. Do. Another specimen.  $\times 2$ . Showing fixed cheek.  
 12. *Sphærexochus latirugatus*, sp. n.  $\times 2$ .

## PLATE XXI.

- Fig. 1. *Ampyx binodulosus*, sp. n.  $\times 2$ .  
 2. *Cyphaspis*? *Harknessi*, sp. n.  $\times 2$ .  
 3. *C. (Törnquistia, subgen. nov.) Nicholsoni*, sp. n.  $\times 4$ .  
 3a. Do. Probably free cheek.  $\times 3$ .  
 4. *Harpes*, sp.  $\alpha$ .  $\times 4$ .  
 5. Do., sp.  $\beta$ .  $\times 4$ .  
 6. *Acidaspis convexa*, sp. n.  $\times 6$ .  
 7. *Lichas bifurcatus*, sp. n.  $\times 2$ .  
 8. *L. bulbiceps*, Phill. MS. From above.  $\times 2$ .  
 8a. Do. From behind.  $\times 2$ .  
 8b. Do. From the side.  $\times 2$ .  
 9. Do.? Hypostome.  $\times 3$ .  
 10. *L. conformis*, Ang. var. *keisleyensis* nov.  $\times 1\frac{1}{2}$ .

## DISCUSSION.

The PRESIDENT congratulated the Author on his important discovery, which, he said, proved that it was yet possible to add greatly to faunas in comparatively well-known rocks. He asked whether it was not possible that some of the smaller forms referred to were merely young specimens of the large species.

Mr. R. S. HERRIES enquired as to the horizon of the Keisley Limestone.

Mr. MARR also spoke.

The AUTHOR, in reply, explained that he had purposely employed the name of 'Keisley Limestone' for the rock from which the fossils had been obtained, because the question of its exact stratigraphical horizon and of that of its much-disputed equivalents elsewhere could not be discussed until its whole fauna had been described. He could, however, by anticipation, say that the affinities of its fauna were with that of the higher beds of the Ordovician, and not with that of the Silurian.

## 21. DESCRIPTIONS OF NEW FOSSILS from the CARBONIFEROUS LIMESTONE.

I. On PEMMATITES CONSTIPATUS, *sp. nov.*, a LITHISTID SPONGE.II. On PALÆACIS HUMILIS, *sp. nov.*, a NEW PERFORATE CORAL, with REMARKS on the GENUS. III. On the JAW-APPARATUS of an ANNELID, EUNICITES REIDLÆ, *sp. nov.* By GEORGE JENNINGS HINDE, Ph.D., F.R.S., F.G.S. (Read April 29th, 1896.)

## [PLATES XXII. &amp; XXIII.]

I. ON PEMMATITES CONSTIPATUS, SP. NOV., A LITHISTID SPONGE FROM THE YOREDALE BEDS OF YORKSHIRE. (Pl. XXII. figs. 1, 1*a-m*.)

ALTHOUGH the thick beds of chert in the Yoredale Series of North-west Yorkshire are largely composed of the remains of siliceous sponges, it is a matter of extreme rarity to meet with an entire specimen of these organisms, and hitherto one has had to be content with describing the detached spicules of various forms with which the beds are crowded. The discovery therefore by Mr. J. Rhodes of a fairly complete sponge in this series of beds is, in itself, of some interest, and still more when the sponge proves on examination to belong to the genus *Pemmatites*, Dunikowski, a genus which, up to the present, has been known only from the Permo-Carboniferous strata of Spitzbergen.

The sponge in question, of which only a single specimen has, as yet, been found, is discoidal, oval in outline, having both upper and under surfaces nearly equally convex, and the margins comparatively sharp. There are no indications of a point of attachment on the underside, nor any traces of a cloacal funnel or depression on the upper. It is 63 mm. in length, 48 mm. in width, and 22 mm. in thickness.

The canal system is very faintly shown; but on the convex upper surface there can be traced canal-apertures, about 0.5 mm. in width, disposed in rows extending from near the centre to the margins (Pl. XXII. fig. 1). These appear to be the openings of excurrent canals, which radiate from near the basal central portion of the sponge in an oblique direction to the upper surface. No incurrent canal-apertures can be recognized on the surface of the sponge, but in thin sections canals about 0.16 mm. in width, bounded by spicules, are shown here and there, which may possibly belong to an incurrent system. (Pl. XXII. fig. 1*l*.)

The skeleton-spicules have a straight or curved shaft, which may be either smooth or notched, and with projecting tubercles, and the extremities are inflated, or notched, or with small processes. They are loosely interlocked together at the ends, and form open anastomosing fibres (Pl. XXII. figs. 1*a-1l*). The spicules range from 0.2 mm. to 0.4 mm. in length and about 0.03 mm. in thickness. There are also irregularly distributed, in certain parts of the sponge,

a few much larger, simple, fusiform spicules, 0·8 mm. in length. No dermal layer has been preserved.

In outward aspect this sponge looks like a flattened waterworn nodule of a greyish tint and a slightly roughened surface, and its organic character was not fully apparent until sections had been made through it. The interior is solid, compact, and consists mainly of chalcedonic silica. The spicules have, for the most part, been replaced by calcite, but they still retain their details of form very perfectly. The fibres of the sponge, examined under the microscope, both in vertical and in transverse sections, have a very irregular and indefinite appearance, and in some places the spicules are loosely massed together, and scarcely show any definite arrangement. The fibres, where best preserved, are crowded with spicules, some parallel with the direction of the fibre, others transverse to its course and projecting into the spaces between the fibres, which are very seldom free from spicules. The spicules are usually so crowded and intermingled together that it is difficult to distinguish individual forms; but, though there is considerable variation, the main type has a straight or curved shaft, with notched or digitate extremities. The spicules appear to be but very lightly connected together; sometimes their shafts are closely apposed, at others they are attached by the interlocking of their short terminal processes or by the knobs at the end of one spicule fitting into the notched ends of a proximate one. No axial canals could be seen in the ordinary spicules of the fibres, but in some of the larger fusiform spicules they have been preserved. These latter spicules appear in small bundles of two or three together in the interspaces of the fibres. A single cylindrical spicule was also met with in the sponge, but it is probably adventitious.

The genus *Pemmatites*, to which this sponge belongs, was established by E. von Dunikowski<sup>1</sup> for some compressed discoidal sponges from the Permo-Carboniferous strata of Spitzbergen, which were considered by this author to be monactinellid in character, from the presence of simple fusiform spicules within the sponge. These, however, proved to be in the interspaces of the fibres of the sponge, while the fibres themselves were described by E. von Dunikowski as the canals. An examination of the type-specimens showed that the spicules of the fibres had been almost entirely obliterated, but a few remained, and these proved that the fibres were originally composed of lithistid spicules.<sup>2</sup> The discovery of the present specimen, in which the fibre-spicules are numerous and well preserved and lithistid in character, and, moreover, are accompanied by some fusiform spicules in the interspaces, fully confirms the lithistid nature of the genus *Pemmatites*.

The present species comes nearest to *P. latituba*, Dun.,<sup>3</sup> in the form of the spicules, but the fibres are much more closely arranged.

<sup>1</sup> 'Ueber Permo-Carbon-Schwämme von Spitzbergen,' K. svenska Vetensk.-Akad. Handl. vol. xxi. (1884) no. 1, pp. 1-18 & pls. i.-ii.

<sup>2</sup> Geol. Mag. 1888, p. 246.

<sup>3</sup> *Op. cit.* p. 16, pl. i. figs. 2 & 12; also Geol. Mag. 1888, p. 249, pl. viii. fig. 7.

I propose to name it *P. constipatus*, from the crowded disposition of the spicules in the fibres. The only specimen as yet found was collected many years since by Mr. John Rhodes from calcareous shale under *Woodocrinus*-limestone (Yoredale Series) at Thringle Scar, north of Gill Wood, above the Main Limestone,  $\frac{1}{8}$  mile north of Throstle Gill and 6 miles north-west of Richmond, Yorkshire. I desire to express my thanks to Mr. Rhodes for the opportunity of describing this interesting form.<sup>1</sup>

## II. ON *PALÆACIS HUMILIS*, SP. NOV., A NEW PERFORATE CORAL, WITH REMARKS ON THE GENUS. (Pl. XXIII. figs. 1-18.)

From the Carboniferous Limestone and shales exposed on the banks of the River Hodder, near Stonyhurst College, Lancashire, the Rev. G. C. H. Pollen, S.J., F.G.S., obtained a series of trilobites and other fossils, including some small bodies which he supposed to belong to the genus *Palæocoryne*, Duncan. At the request of Dr. H. Woodward,<sup>2</sup> who described the trilobites from these rocks, I undertook an examination of these peculiar bodies. Though it was apparent that they did not belong to *Palæocoryne*, I could not at first recognize their relationship to any other organism, and it was not until after repeated study at different intervals that it occurred to me to compare them with specimens of *Palæacis cuneiformis*<sup>3</sup> (Haime), M.-Edw., which I had myself collected many years previously from the Lower Carboniferous rocks of Spergen Hill, Indiana. It could then be seen that, though differing considerably in general form, they were so far structurally similar that they could be included in the same genus.

In the meantime some other small dubious fossils from the soft shales of the Lower Culm Measures at Codden Hill, near Barnstaple, came under my notice, which, like those from the Hodder, differed from anything I had previously met with. Unlike these latter, however, they were only in the form of casts, and consequently less easily recognizable. A close study of these brought to light the curious fact that not only do they belong to the genus *Palæacis*, but even to the same species as the Hodder specimens. Though only casts, they serve to illustrate the structure of the species, and supplement the evidence derivable from the specimens which have their walls preserved.

The specimens from the banks of the Hodder are nearly all in a soft shale or mudstone, and in breaking up the rock the under surface of the fossil, in the form of a St. George's cross, is almost invariably exposed (Pl. XXIII. fig. 1), while the upper surface, with the apertures of the corallites, is covered by the matrix, and can, as a rule, be seen only by grinding down the rock or removing it with a needle (Pl. XXIII. figs. 2 & 3). The walls retain their original structure of carbonate of lime, but the interior of the calices and

<sup>1</sup> [Since this paper was read the specimen has been placed in the Museum of Practical Geology, Jermyn Street.]

<sup>2</sup> Geol. Mag. 1894, p. 481.

<sup>3</sup> Hist. Nat. Corall. vol. iii. (1860) p. 171, Atlas, pl. x l. fig. 3.

the mural pores are frequently in part filled with iron pyrites, and, as the walls are thin and delicate, the preparation of thin sections is rendered difficult.

*Specific Characters.*—Corallum small, quite free and without any trace of attachment. In its fullest development it consists of four depressed corallites, starting, on the same plane, from a common centre, nearly at right angles to each other; in some specimens only three corallites are present, in others two; while simple forms of but a single corallite are also not uncommon. In the larger forms with four corallites (Pl. XXIII. figs. 1, 2, 3 & 4) the central portion of the base is flattened, and the corallites extend from it at first in a nearly horizontal direction, and then they gradually curve upwards and outwards, so that their apertures are somewhat oblique. The free portions of the corallites are subcylindrical, in section varying from circular to elliptical. The corallites are not always of the same length; usually the two forming the transverse axis are subequal and shorter than those of the longitudinal axis, and in this axis one corallite is, as a rule, markedly longer than the other (Pl. XXIII. figs. 3 & 4). The outer surface of the corallum is marked by distinct ridges, with sharp continuous edges, which, in the distal or free portions of the corallites, are longitudinal, straight, or slightly wavy, and subparallel, but in the central portions of the corallum, both on the basal and upper surfaces, they are usually broken up into short, discontinuous, somewhat labyrinthine patterns. In the longitudinal furrows between the surface-ridges there are rows of subcircular mural pores, disposed in alternating series, which penetrate the wall direct and open into the visceral chamber of the corallites. These mural pores are not limited to the free lateral portions of the corallites, but they are present in the basal portions as well, some connecting the visceral chambers of adjacent corallites, while others communicate with the exterior (Pl. XXIII. figs. 6, 9 & 10). The mural pores are but seldom exposed to view on the outer surface of the coral, unless when it is weathered or rubbed down.

The calice, or the interior of the corallite, is conical or turbinate in form; the inner surface of the wall shows the rows of mural pores, and the spaces between these are nearly smooth or marked by slightly impressed lines, but there are no indications of granulations, tubercles, or septa, to correspond with the ridges of the exterior surface (Pl. XXIII. fig. 12). The apertural margins of the corallites are thin and slightly crenulate from the projection of the edges of the wall-ridges.

In the specimens which consist of only two corallites, these are joined end to end, so that, viewed laterally, the forms appear as short, nearly cylindrical, curved pipes, with a circular aperture at each end (Pl. XXIII. figs. 5 & 6). The internal form of these corallites is well shown in the casts from the Lower Culm (fig. 6). From the central portion of these twin forms of corallum one or two additional corallites are occasionally developed, but in several examples there are no traces of any lateral buds, and the corallum appears to have permanently remained a twin form. In the simple

examples of the species the corallum has somewhat the form of a rifle-bullet: its basal end is conical and evenly rounded, with no trace of attachment; the outer surface has longitudinal ridges, the same as in the compound forms; and the wall, both of the sides and base, is similarly traversed by direct mural pores (Pl. XXIII. figs. 7 & 8). The calice is more directly conical than the outer form, so that the basal portion of the wall is thicker than the upper part, and the mural pores opening on the exterior through this thickened base have somewhat the character of canals (Pl. XXIII. fig. 10). In no example yet discovered are there more than four corallites present.

The microscopic structure of the wall of this species is of radiating crystalline fibres, like that of corals generally (Pl. XXIII. fig. 15), and in its present condition of preservation it is closely similar in appearance under the microscope to a thin section of *Favosites*, sp., from the Devonian, with which I have compared it. The mural pores also are comparable with those of *Favosites* and *Pleurodictyum*. Neither epitheca nor cœnenchyma is present, and there is no indication of tabulæ or of solid non-perforate tissues filling the base of the calices.

The diameter of the normal corallum with four corallites ranges from 10 to 15 mm.; in length the individual corallites vary between 4 and 6 mm., and in width, at their summits, between 3 and 4.5 mm. There are from 20 to 30 longitudinal ridges, and a corresponding number of rows of mural pores, in a corallite.

The present species, which I propose to name *P. humilis*, is distinguished from *P. cuneiformis*, Haime, the typical species, in its general form and the size and disposition of the corallites; the external ridges, moreover, are of a coarser character, and they are more regularly arranged. The resemblance to *P. (Sphenopoterium) obtusa*, Meek & Worthen, sp.,<sup>1</sup> is less apparent, for this latter form is considerably larger, its walls are relatively very thick, and the corallites are wide and openly conical. *Palæacis (Sphenopoterium) enormis*, Meek & Worthen,<sup>2</sup> and its variety *depressa*, more nearly correspond in size with the present species, but the surface-striæ are said to be broken up into irregular granules. Owing to the brief description of this form, no nearer comparison is possible. For reasons given below, I consider that *P. humilis* has no generic relations with (*Palæacis*) *Hydnopora? cyclostoma*, Phillips.<sup>3</sup>

*Distribution*.—Fairly common in shale or mudstone associated with limestones and chert exposed in the banks of the River Hodder, below Stonyhurst College, Lancashire. According to Mr. R. H. Tiddeman,<sup>4</sup> the rocks belong to the Southern or Bowland type of the Carboniferous Limestone of Lancashire, and come in between the Clitheroe Limestones and the Pendleside Limestones. Collected by the Rev. G. C. H. Pollen.

Also in soft decayed shale of the Lower Culm Measures at Overton

<sup>1</sup> Proc. Acad. Nat. Sci. Philad., Oct. 1860, p. 447.

<sup>2</sup> Geol. Surv. Illinois, vol. ii. (1866) pl. xiv. figs. 1 & 2.

<sup>3</sup> 'Geol. Yorkshire,' vol. ii. (1836) p. 202, pl. ii. figs. 9 & 10.

<sup>4</sup> Geol. Mag. 1894, p. 482.

Quarry and at Hannaford Quarry, near Barnstaple, North Devon. Only casts are here found; they are associated with casts of radiolaria, trilobites, etc.

*Remarks on the Genus Palæacis (Haime), Milne-Edwards.*

Various and conflicting opinions have been advanced as to the characters and systematic position of this genus. It has been placed alternately with corals and sponges, and, though latterly it has been generally regarded as a perforate coral, its real characters have not yet been definitely settled. This uncertainty appears to me to be in part due to the fact that some authors have placed in the genus certain forms which widely differ from the typical species, and have then defined its characters more from these foreign forms than from the original types.

As is well known, Milne-Edwards<sup>1</sup> founded the genus on some small wedge-shaped specimens from the Subcarboniferous Limestone of Spergen Hill, Indiana, which are described as having the polypary free, with a finely vermiculate cœnenchyma. The calices were stated to be divided by two large septa, and also furnished with thirty to forty fine striæ, supposed to represent septa which had been destroyed. The author was not positive as to the coral-nature of these bodies, but he provisionally placed the genus with the Madreporidæ and named the type-species *Palæacis cuneiformis*. It may here be remarked that later observations have shown that the author was mistaken, both with respect to the vermicular cœnenchyma and the two large septa in this species; but, as he gave fairly good figures of the forms described, no doubt has remained as to their identity.

The same species, with others allied to it, were independently described nearly at the same time by Meek and Worthen<sup>2</sup> under the generic term *Sphenopoterium*. They were considered to be corals allied to *Cyathoseris*, M.-E. & H.; but a few years afterwards these same authors,<sup>3</sup> relying on the authority of Prof. Verrill, removed the genus from corals and placed it with sponges. It is now acknowledged that *Sphenopoterium* is a synonym of *Palæacis*, and priority has been generally conceded to this latter.

In 1866 K. von Seebach<sup>4</sup> referred the genus to perforate corals and proposed two new species, which have since been regarded as synonyms of *Palæacis obtusa*, Meek & Worthen, sp. This author does not appear to have examined any examples of the type-species or microscopic sections of the forms described, but states that there was a vermiculate perforate cœnenchyma, in which the individual calices were enclosed, and he agrees with Milne-Edwards in assigning the genus to the Madreporidæ.

<sup>1</sup> Hist. Nat. Corall. vol. iii. (1860) p. 171, Atlas, pl. n. 1. fig. 3.

<sup>2</sup> Proc. Acad. Nat. Sci. Philad. 1860, p. 447.

<sup>3</sup> Geol. Surv. Illinois, vol. ii. (1866) p. 145.

<sup>4</sup> Nachr. k. Gesellsch. Wiss. zu Göttingen, 1866, p. 241; also Zeitschr. deutsch. geol. Gesellsch. vol. xviii. (1866) p. 304.

Dr. Kunth<sup>1</sup> next undertook a description of the genus, but he professedly based his observations on *Ptychochartocyathus laxus*,<sup>2</sup> Ludwig, a coral which he considered to be congeneric with *Palæacis*; the form that he describes and figures, however, is by no means similar to that placed under this name by Ludwig, but appears rather to belong to *Hydnopora* (?) *cyclostoma*, Phillips,<sup>3</sup> first described by Phillips from the Carboniferous Limestone of Yorkshire.

Prof. de Koninck<sup>4</sup> followed nearly in the same path as Kunth, by accepting *Hydnopora* (?) *cyclostoma*, Phill., as a genuine *Palæacis*, and then relying on its characters for the definition of the genus. Prof. Ferd. Roemer,<sup>5</sup> on the other hand, maintained that *H.* (?) *cyclostoma* was not congeneric with *Palæacis*, mainly on the ground that it was an attached and not a free form, but subsequently<sup>6</sup> he retained it in the genus, though still regarding it as probably distinct.

In 1878 Messrs. Etheridge and Nicholson<sup>7</sup> published an excellent paper, 'On the Genus *Palæacis* and the Species occurring in British Carboniferous Rocks,' in which, for the first time, reference is made to the microscopic structure of the various forms. These authors, however, agreed with De Koninck that *H.* (?) *cyclostoma*, Phill., really belonged to the genus, and as a consequence the characters of this particular form, which is very fully described and illustrated, largely enter into their definition of the genus. They reach no final decision as to the systematic position of *Palæacis*, though they consider it more closely allied to sponges than to corals. Since then, however, Prof. Nicholson<sup>8</sup> has fully acknowledged that *Palæacis* is a perforate coral, but it should be remembered that this conclusion refers rather to *Hydnopora* (?) *cyclostoma*, Phill., than to the type-species of the genus.

In order to determine the question as to the rightful characters of *Palæacis* and whether *Hydnopora* (?) *cyclostoma*, Phill., can properly be incorporated in this genus, it will be necessary to consider separately the main features of *P. cuneiformis*, M.-Edw., the undoubted type of the genus, and of *H.* (?) *cyclostoma*, Phill., and then compare them together.

Taking first *P. cuneiformis*, a difficulty is experienced at the outset owing to the rarity of examples of this species and their unfavourable condition of preservation. I have had mainly to rely upon a few specimens, obtained from the same beds at Spergen Hill as those that yielded the type-forms, with which they correspond very closely. They are, however, siliceous and replaced in part by beekite, so that their microscopic characters are obscured. The

<sup>1</sup> Zeitschr. deutsch. geol. Gesellsch. vol. xxi. (1869) p. 183.

<sup>2</sup> Palæontographica, vol. xiv. (1866) pp. 189, 231, pl. xlvii. fig. 14, pl. lxix. fig. 2a.

<sup>3</sup> 'Geol. Yorkshire,' vol. ii. (1836) p. 202, pl. ii. figs. 9 & 10.

<sup>4</sup> 'Nouv. Recherches Anim. foss. Terr. Carb. Belgique,' 1872, pt. i. pp. 154-161.

<sup>5</sup> 'Lethæa Palæozoica,' Atlas, 1876, pl. xxxix. Explanation.

<sup>6</sup> *Ibid.* Text, 1880, p. 515.

<sup>7</sup> Ann. & Mag. Nat. Hist. ser. 5, vol. i. (1878) pp. 206-227, pl. xii.

<sup>8</sup> 'Man. of Palæontology,' 3rd ed. vol. i. p. 310.



specimens discovered by Mr. Spencer G. Perceval<sup>1</sup> from the Lower Limestone Shales of Combe Down, Henbury, near Bristol, have lately been acquired by the British Museum (Nat. Hist.), but they are also partially silicified and do not show the structure so clearly as the American examples. The colony is small, wedge-shaped, with a compressed base which is quite free; there are from two to four corallites arranged in a single lateral series. (Pl. XXIII. figs. 16 & 16 a.) In some cases the upper margins of the corallites project beyond the general surface, and are free, sharp-edged, and minutely crenulate. The outer surface of the corallum has longitudinal, subparallel, slightly wavy ridges, and in the furrows between these are rows of mural pores, which extend directly through the wall and open into the interior of the calices. The calices are conical, varying from nearly circular to oval or elliptical in section; within they show the rows of pores, and between these are faintly-marked ridges or lines, which may represent septa. Pores or canals also pass between and connect the corallites. The wall in the compressed basal portion of the corallum is now, in the specimens examined, solidly replaced by silica, and its original structure doubtful, but there are no indications of a vermiculate cœnenchyma, and it may have been perforated by simple pores or straight canals, like those in the upper portion of the corallum, which, moreover, closely resemble those already described in *P. humilis*.

Turning now to *Hydnopora* (?) *cyclostoma*, Phill., of which examples are fairly common in the Carboniferous Limestone of Northumberland, and of Fifeshire and other places in Scotland, we find it growing in small colonies usually of from two to six corallites, but in some cases twelve have been observed. The corallum is invariably attached to some foreign body, and its basal portion in part conforms to the figure of the shell or other organism to which it is affixed, and in part is free and covered with concentric wrinkles or ridges. The calices are open, with nearly straight sides; their margins may be either free or on a level with adjoining calices; and the interiors are furnished with numerous tubercles or blunt spines, which are crowded over the bottom of the cup and disposed regularly in rows on the sides, where they apparently represent the septa. The outer surface of the coral has interrupted sinuous ridges and granules, with, in places, irregular apertures between. The structure of the wall, as shown in sections, is of a remarkable character. The basal portion or floor within each calice, and the sides as well, nearly if not quite up to the margin, consists of a layer of solid, non-perforate, calcareous tissue, outside of which, occupying the space between the calices and also forming the basal layer of the corallum, there is a well-marked layer of an openly porous or lacunar reticulate tissue, strikingly similar to that of recent perforate corals. This layer, which may be considered as a porous cœnenchyma, has been very carefully described and figured by Etheridge and Nicholson.<sup>2</sup>

The minute structure in *H. (?) cyclostoma* is of radiate crystalline

<sup>1</sup> Geol. Mag. 1876, p. 267.

<sup>2</sup> Ann. & Mag. Nat. Hist. ser. 5, vol. i. (1878) p. 215, pl. xii. figs. 7 & 8.

fibres precisely similar to that in recent corals. Though in reality compact, under certain conditions of preservation, microscopic sections of it give the erroneous impression of being traversed by minute tubuli.

It will be seen on comparing these two forms, *Palæacis cuneiformis*, M.-Edw., and *Hydnopora* (?) *cyclostoma*, Phill., that the differences between them are of too radical a character to allow of their inclusion in the same genus. In the former the walls are simply perforated by mural pores or canals analogous to those in Palæozoic Favosite corals, while in the latter there is a distinct lacunar coenenchyma, similar to that in modern perforate corals, and moreover the interior of the calices has a solid non-perforate layer which carries the blunt septal spines or tubercles. Minor differences are the wrinkled outer surface and the attached mode of growth in *H.* (?) *cyclostoma*.

Of the other species referred to *Palæacis*, that herein described as *P. humilis* approaches nearest the type-species.<sup>1</sup> *P. obtusa*, Meek & Worthen, sp. (= *P. cymba*<sup>2</sup> and *P. umbonata*,<sup>3</sup> Von Seebach), *P. compressa*,<sup>4</sup> M. & W., sp., and *P. enormis*, M. & W., sp., form a group markedly distinct from the type-species of the genus and *P. humilis* in the larger size of the corallum, the openly conical and shallow form of the calices and the much greater thickness of their walls. As regards the structure of the walls in these forms nothing definite is as yet known. In the specimens of *P. obtusa* from Spergen Hill, Indiana, belonging to the British Museum (Natural History), which I have examined, the interior is now a solid mass of silica and all traces of pores or canals have been obliterated, and it therefore remains an open question whether they were similar to *P. cuneiformis* in this feature or not. The principal grounds for including them under *Palæacis*, M.-Edw., are their general form, striated or ridged outer surface, and free condition of growth.

[Since this paper was read Mr. E. T. Newton, F.R.S., has brought to my notice a specimen of *Palæacis obtusa*, Meek & Worthen, sp., from the Carboniferous Limestone of Hook Point, Wexford, Ireland, now in the Jermyn Street Museum, in which the structure has not been altered by silicification, so that the character of the wall in this species can be determined. The specimen in question (Pl. XXIII. fig. 18) is partially weathered out on the surface of a piece of limestone; it is wedge-shaped, free, about 13 mm. in width, and nearly the same in height. There are six shallow, openly conical corallites at the summit. The outer surface is covered with fine, somewhat wavy striæ or ridges, which have a general direction towards the centre of the base; in places they are discontinuous and interrupted. A vertical median section shows that the corallite-walls are regularly perforated by pores and canals, which connect adjoining calices and also pass through to the exterior (Pl. XXIII. fig. 18 a).

<sup>1</sup> Geol. Surv. Illinois, vol. ii. (1866) p. 233, pl. xvii. figs. 2 a-e.

<sup>2</sup> Zeitschr. deutsch. geol. Gesellsch. vol. xviii. (1866) p. 309, pl. iv. figs. 4 a & b.

<sup>3</sup> *Ibid.* figs. 3 a & b.

<sup>4</sup> *Op. jam cit.* p. 234, pl. xvii. figs. 1 a-c.

They are present in the basal as well as in the lateral and marginal portions of the corallum, and they closely correspond to those in *P. cuneiformis* and *P. humilis*. There are no indications of a porous or lacunar cœnenchyma. This specimen is smaller and the surface-ridges are somewhat finer than in the Indiana examples of the species. De Koninck<sup>1</sup> has already recorded the occurrence of this form in the beds at Hook Point.—May 18th, 1896.]

The genus *Palæacis*, accepting *P. cuneiformis*, M.-Edw., as the type, appears to represent a distinct family of perforate corals in some features more nearly allied to the Favositidæ than to the Madreporidæ or Poritidæ. Thus, for example, with respect to the perforation both of the bases as well as the sides of the corallites by mural pores and canals, we find a similar condition of things in *Pleurodictyum granuliferum*, Schlüter,<sup>2</sup> from the Middle Devonian of the Eifel, and this moreover is quite a free form.

By the removal of *Hydnopora* (?) *cyclostoma*, Phill., from *Palæacis* this form must represent an independent genus for which I venture to propose the name of *Microcyathus*. Ferd. Rœmer<sup>3</sup> considered that it might be included under *Ptychochartocyathus*, Ludwig,<sup>4</sup> but if any reliance is to be placed on the description and figures of the type of this genus, *P. laxus*, Ludwig, there is certainly no generic relation to *Hydnopora* (?) *cyclostoma*, Phill. Ludwig states positively that *P. laxus* has thick non-perforate walls, no mention is made of a lacunate cœnenchyma, and, judging from the figure, there is no resemblance in its mode of growth and the disposition of the calices to *H.* (?) *cyclostoma*, Phill.

In this connexion it will be desirable to mention another coral, the *Astræopora antiqua*, M'Coy,<sup>5</sup> from Hook Point, Wexford, which has been regarded as a synonym of *H.* (?) *cyclostoma*, Phill. I have not seen the type-specimen, but examples from the same locality as the type, which correspond with M'Coy's figures, are in the Jermyn Street Museum, and through the kindness of Mr. E. T. Newton, F.R.S., a section has been prepared from one of these, which I have examined. The calices are very shallow, and the walls apparently consist of compact tissue, in which there are some irregular tubes—as if due to some boring organism. The section was not altogether clear, but there were no indications of a lacunar intermediate tissue between the calices as in *Microcyathus* (*Hydnopora*?) *cyclostoma*, and it is evidently generically distinct from this latter.

In conclusion I wish to express the great obligations under which I am to the Rev. G. C. H. Pollen, S.J., F.G.S., for supplying me with the specimens of *Palæacis humilis*, and I am glad to state that this gentleman intends presenting the type-forms to the British Museum (Natural History).

<sup>1</sup> 'Nouv. Rech. Anim. Foss. Terr. Carb. Belgique,' pt. i. 1872, p. 158.

<sup>2</sup> 'Anthozoen des rheinischen Mittel-Devon,' Abhandl. k. preuss. geol. Landesanst. 1889, p. 193, pl. iv. figs. 5-8.

<sup>3</sup> 'Lethæa Palæozoica,' Atlas, 1876, pl. xxxix. Explanation.

<sup>4</sup> Palæontographica, vol. xiv. (1866) pp. 189, 231, pl. xlvii. fig. 14, & pl. lxix. fig. 2a.

<sup>5</sup> 'Syn. Carb. Limest. Foss. Ireland,' 1844, p. 191, pl. xxvi. fig. 9.

III. ON THE JAW-APPARATUS OF AN ANNELID (*EUNICITES REIDII*, SP. NOV.) FROM THE LOWER CARBONIFEROUS OF HALKIN MOUNTAIN, FLINTSHIRE. (Pl. XXII. figs. 2, 2 *a*, & 2 *e*.)

In the numerous examples of the jaw-plates of annelids described by the writer some years since from the Palæozoic rocks of Canada,<sup>1</sup> England,<sup>2</sup> Scotland,<sup>3</sup> and the Isle of Gotland,<sup>4</sup> without exception the small constituent plates of the jaw occurred separately on the rock-surfaces, detached from the relative positions which they occupied in the living condition of the animal. These small bodies have subsequently been discovered in the Upper Silurian rocks of New South Wales by Mr. Robert Etheridge,<sup>5</sup> and in the Middle Devonian of New York State by Dr. J. M. Clarke,<sup>6</sup> and always in a similarly detached condition, with the single exception of the jaw-apparatus of a species of *Arabellites*, discovered by Dr. Clarke, in which the different dentated plates, now somewhat fragmentary, are shown in the natural position that they occupied in the jaw-sac of the animal.

I propose now to describe another and more perfect specimen than that just referred to, in which the upper jaw-plates of a species of *Eunicites* have been preserved, showing their natural position with respect to each other. The specimen in question was discovered by Miss Margery A. Reid in some thin black fissile shales of the Lower Carboniferous formation at Halkin Mountain, Flintshire. In splitting open a piece of the shale the jaw was found standing out in relief on the surface of one piece and the counterpart on the other. A portion of one of the large pincers and of one of the dental plates must have been broken away when the shale was splintered; with these exceptions the jaw-apparatus differs but little in appearance from that of a recent annelid. It has precisely the same glossy black aspect as the upper jaws of recent annelids, and, like these, must have been originally of chitinous material.

As now exposed, the jaw-apparatus shows its upper or free surface. It consists on each side of a support, pincer, and dental plate; probably paragnaths were also originally present, but only a single one of these has been found. The entire length of the jaw is 5·4 mm., and its greatest width 4·1 mm. The supports *a* (Pl. XXII. figs. 2 & 2 *a*) are approximately oblong in outline, with a straight upper margin where they come into contact with the base of the pincer, nearly straight sides, and rounded ends. The surface has a slightly elevated ridge, which runs obliquely. They are now about 1·2 mm. in length by ·7 mm. in width. It is probable that they were longer than is now shown, judging from an impression on the shale, which indicates that they were originally prolonged to a blunted

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxv. (1879) p. 370.

<sup>2</sup> *Ibid.* vol. xxxvi. (1880) p. 368.

<sup>3</sup> *Ibid.* vol. xxxv. (1879) p. 386.

<sup>4</sup> Bihang till k. svenska Vet.-Akad. Handl. vol. vii. (1882) no. 5.

<sup>5</sup> Geol. Mag. 1890, p. 339.

<sup>6</sup> Sixth Annual Report of the State (New York) Geologist, for the year 1886. Albany, 1887.

base. The pincers *b* (figs. 2 & 2 *a*) are robust, with straight bases where resting on the supports; above the base there is a well-marked curve, terminating in an angle where the pincer is widest; from this the plate gradually curves upwards and ends in a stout hook. There is a rounded ridge along the outer margin of the pincer, and a distinct nodular elevation at the narrow basal end. The pincers are 3·8 mm. in length and 1·5 mm. at their greatest width. The dental plates *d* (figs. 2 & 2 *a*) are elongate, with a nearly straight base; at the anterior end is a stout curved denticle, followed by a much smaller one, and then by a series of stout conical denticles, of which there are nine in the left plate, but only five are shown in the cast of the right plate. The denticles in the right plate *d* (figs. 2 & 2 *a*) as shown in the cast are stronger than those of the left (*c*), and though one or two may be concealed I do not think there were as many as in the left. The position of these dental plates in regard to the pincers is remarkable. They now rest with the curved anterior tooth and the succeeding series of denticles turned towards the exterior side of the jaw and having their straight bases facing each other as shown in fig. 2, whereas in recent allied forms these plates have their dentated margins facing each other, and their straight or curved bases are within or beneath the curved hollows of the pincers. It is difficult to see how in the fossil the dental plates could act conjointly with the pincers in their present position, and I can only suppose that they have been turned outward by subsequent pressure. In the specimen, as shown in fig. 2, the greater portion of the right dental plate (*d*) has broken away, but the cast of it is preserved in the counterpart, as seen in fig. 2 *a*, while the left plate (*c*) is complete, with the exception of the anterior hook which is shown in the cast. The length of this plate is 3·3 mm., and its width at the anterior end is 1·1 mm. A cast of a nearly similar but somewhat smaller dental plate occurs in a detached condition on another slab of shale (fig. 3). I cannot find positively that any unpaired dental plate was present in the specimen, though it is possible that it might be hidden beneath the upper plate (*c*). Attached near the side of one of the pincers was a small plate, roughly triangular in outline, with four blunt denticles on one margin and a small projection from the opposite angle, which may possibly have been a paragnath of the same specimen, though it is relatively small in comparison with similar plates in recent forms (Pl. XXII. fig. 2 *e*). Another minute detached plate, which may have been a paragnath, is shown (fig. 4), but there are no grounds for connecting it with the larger specimen. No traces of any structure resembling the lower jaws of an annelid corresponding to this upper jaw-apparatus have been discovered.

Notwithstanding the peculiar position of the dental plates in this jaw, the individual pieces correspond with sufficient closeness to those of the recent *Eunicia* family for this to be included in the genus *Eunicites*, Ehlers, as a new species, *Eunicites Reidice*, in honour of its discoverer. The only annelid-remains known hitherto from the Lower Carboniferous are some detached plates from the shaly limestone of Cults, Fifeshire, and among these is a pincer

of *Eunicites*, which is smaller and more slender than that of the form here described.

The present specimen was discovered in some dark, thin, shaly beds in the Carboniferous Limestone Series near Bwlch, about 1 mile N.N.E. of Nannerch, Halkin Mountain, Flintshire; and associated with it in the same beds were fragments of polyzoa and some trilobites, the latter of which have been determined by Mr. E. T. Newton as *Phillipsia Eichwaldi*, Fischer. The specimen has been presented by Miss Reid to the Museum of Practical Geology, Jermyn Street.

## EXPLANATION OF PLATES XXII. & XXIII.

### PLATE XXII.

*Pemmatites constipatus*, sp. nov. Figs. 1, 1 a-1 m.

Fig. 1. The sponge showing the upper surface. Natural size.

1 a, 1 b, 1 c. Spicules from the fibres showing their individual forms. Enlarged 60 diameters.

1 d, 1 e, 1 f, 1 g, 1 h. Spicules from the fibres showing their mode of union. Enlarged 60 diameters.

1 i. A portion of a spicular fibre as shown in a horizontal section of the sponge. Enlarged 60 diameters.

1 k. A portion of a spicular fibre as shown in a vertical section of the sponge. Similarly enlarged.

1 l. A portion of a spicular fibre with canals, as shown in a horizontal section. The spicules are too crowded to be individually distinguished. Similarly enlarged.

1 m. Fusiform spicules (fragmentary) from the interior of the sponge. Enlarged 60 diameters.

From the Yoredale Series at Thringle Scar, near Richmond, Yorkshire. Collected by Mr. John Rhodes, and now in the Museum of Practical Geology, Jermyn Street.

*Eunicites Reidie*, sp. nov. Figs. 2, 2 a, 2 e.

Fig. 2. The jaw-apparatus: (a) The supports. (b) The pincers. (c) The dental plate of the left side. (d) The corresponding plate of the right side, imperfect. A portion of the pincer on the left side is also missing. Enlarged 10 diameters.

2 a. The same as shown in the counterpart, similarly enlarged.

2 e. A paragnath, probably belonging to the same jaw.  $\times 10$ .

3. The cast of a dental plate, detached.  $\times 10$ .

4. A small paragnath, detached.  $\times 10$ .

5. A fragment of a pincer, detached.  $\times 10$ .

The specimens are from the shaly beds in the Carboniferous Limestone Series near Bwlch, about 1 mile N.N.E. of Nannerch, Halkin Mountain, Flintshire; they are preserved in the Museum of Practical Geology, Jermyn Street. Collected by Miss M. A. Reid.

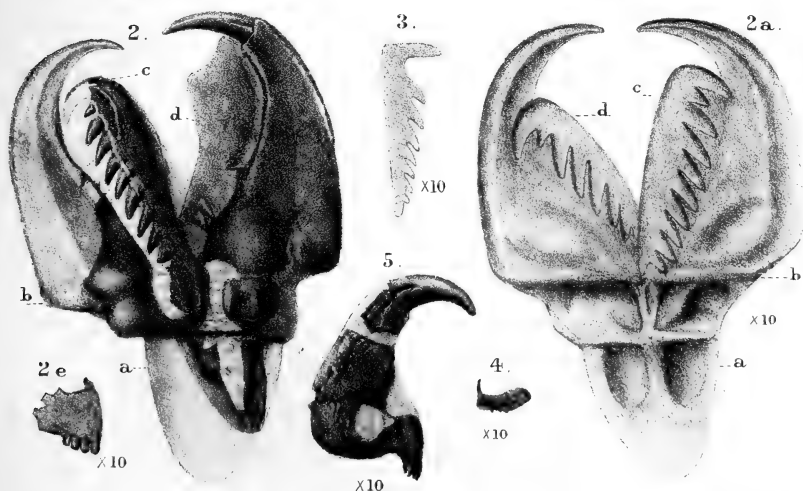
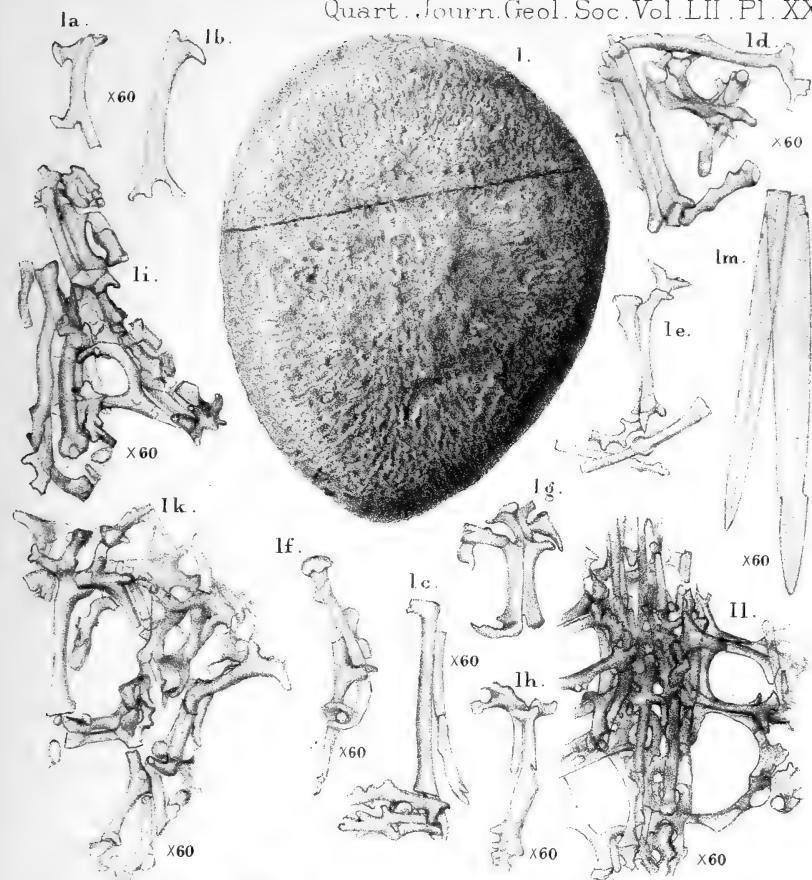
### PLATE XXIII.

*Palæacis humilis*, sp. nov. Figs. 1-15.

Fig. 1. A complete specimen as it occurs in the rock, showing the basal portion and the surface-ridges. Enlarged 2 diameters. From the Carboniferous Limestone, River Hodder, Stonyhurst, Lancashire.

2. The upper surface of a fairly complete specimen with four corallites.  $\times 2$  diameters.

3, 4. The upper and under surfaces of a specimen in which one of the corallites is much longer than the others. This is entirely free from the rock-matrix.  $\times 2$  diameters.



A. T. Hollick lith.

Mintern Bros. imp.

PEMMATITES CONSTIPATUS, sp. nov.  
AND EUNICITES REIDIÆ, sp. nov.





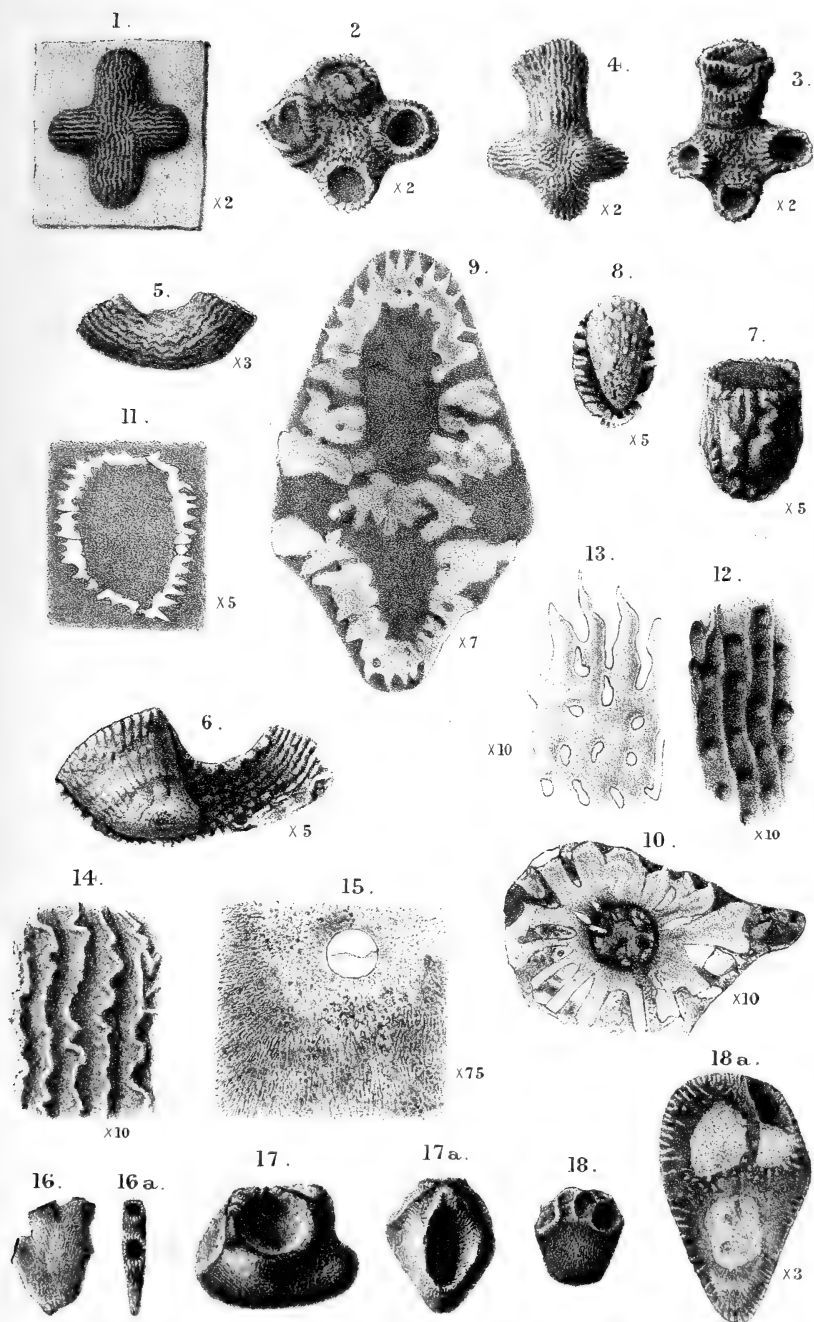




Fig. 5. A specimen consisting of only two corallites, viewed laterally.  $\times 3$  diameters. River Hodder.

6. The cast of a specimen consisting of only two corallites, showing in the one half the solid infilling of the calice with the mural pores, and in the other the casts of the outer wall and the longitudinal ridges.  $\times 5$  diameters. From decayed shale in the Lower Culm Measures at Hannaford Quarry near Barnstaple.
7. A specimen consisting of but a single corallite, quite free from the matrix.  $\times 5$  diameters. River Hodder.
8. A cast of another single specimen, showing the thickness of the wall at the base and the form of the interior of the calice.  $\times 5$  diameters. Lower Culm Measures, Hannaford Quarry.
9. A horizontal section of a specimen with four corallites, showing the mural pores between contiguous corallites and those opening to the exterior.  $\times 5$  diameters. From the River Hodder.
10. A transverse section of a single corallite near the base, showing the thickness of the wall and the mural pores or canals.  $\times 10$  diameters. River Hodder.
11. A transverse section of a corallite-wall near the summit.  $\times 5$  diameters.
12. A portion of the inner surface of a calice, showing the mural pores.  $\times 10$  diameters.
13. A portion of the under surface of a corallite which has been rubbed down, showing the mural pores.  $\times 10$  diameters. River Hodder.
14. Portion of the outer surface, showing the longitudinal ridges.  $\times 10$  diameters.
15. Portion of a translucent microscopic section of the wall showing the fibro-crystalline structure and one of the mural pores.  $\times 75$  diameters.
- 16, 16 a. *Palæacis cuneiformis*, M.-Edw. Front and side view of a specimen with four corallites. Natural size. From the Subcarboniferous (St. Louis) Group, Spargen Hill, Indiana.
- 17, 17 a. *Palæacis obtusa*, Meek & Worthen, sp. Front and side view of a specimen with five calices. Natural size. From the Subcarboniferous Limestone, Keokuk, Iowa.
18. The same. Front view of a small specimen with six calices. Natural size. From the Carboniferous Limestone of Hook Point, Wexford. The specimen belongs to the Jermyn Street Museum.
- 18 a. The same. A vertical median section of the same specimen, showing three corallites, now filled with the rock-matrix and the mural pores, and canals traversing the walls.  $\times 3$  diameters.

#### DISCUSSION.

Mr. STRAHAN remarked on the richness of Halkin Mountain in fossils, and suggested that it would be advisable to fix more exactly than seemed to have been done the locality and horizon in the limestone of the annelid described. He congratulated Miss Reid on the discovery of this unusually perfect specimen.

Prof. T. RUPERT JONES also spoke.

The AUTHOR replied that he would endeavour to obtain more definite particulars as to the exact horizon of *Eunicites*, and thanked the Fellows for the reception accorded to his paper.

22. *On an ALPINE NICKEL-BEARING SERPENTINE, with FULGURITES.*  
By Miss E. ASTON, B.Sc., with PETROGRAPHICAL NOTES by  
T. G. BONNEY, D.Sc., LL.D., F.R.S., V.P.G.S., Professor of  
Geology and Mineralogy in University College, London. (Read  
March 11th, 1896.)

THE rocky peak of the Riffelhorn (9616 feet), well known to all who have visited Zermatt and the Gornergrat, forms part of a large mass of serpentine which seems to vary slightly in composition and is generally more or less schistose, becoming in places quite slaty—the effect of pressure.<sup>1</sup> On the summit of this peak the compass, as is well known, exhibits the most extraordinary variations, and the rocks appear to be not seldom struck by lightning.<sup>2</sup> Specimens exhibiting fulgurites were collected on it by both Prof. W. Ramsay and Mr. J. Eccles in 1890, the examination of which has led to some interesting results.

The geologist, in working over different parts of this large mass of serpentine, observes that, where the original structure is not obscured by subsequent pressure, the rock is not quite uniform in character—one variety being an ordinary dark green bastite-serpentine (sometimes also containing augite), the other being a little tougher and harder under the hammer and slightly rougher when handled; in short, it is not quite so normal a serpentine as is the other variety. Of this harder kind the upper part (at any rate) of the Riffelhorn peak is composed.

It will be convenient to speak of the microscopic structure and chemical composition of the rock before describing the effects of the lightning, though the latter was the reason that induced Prof. Ramsay to ask the present authors to investigate the former questions.<sup>3</sup>

Slices for microscopic examination were prepared from four separate specimens. These exhibit slight varietal differences, which, however, are comparatively unimportant. Hence their constituent minerals may be described together. These are:—

- (a) A clear colourless mineral in flakes, which are sometimes rather irregular in outline and vary in size up to about .025 inch. They have a mica-like cleavage, but it is hardly so well defined as in that mineral. The smaller flakes, with crossed nicols, give bluish-white and dull blue tints; the larger fairly bright colours. The majority give straight extinction, but not a few flakes (which correspond in all other respects) extinguish at

<sup>1</sup> See, for details, Bonney, *Geol. Mag.* 1890, p. 533.

<sup>2</sup> Tyndall, 'Glaciers of the Alps,' 1860, pp. 141–145.

<sup>3</sup> Miss Aston is responsible for the chemical work; Prof. Bonney for that with the microscope.

small angles up to about  $10^{\circ}$ .<sup>1</sup> The mineral (if it is a single one) in some respects resembles antigorite, but that is defined as slightly green in colour, with one very well-marked cleavage, a slight dichroism and straight extinction.<sup>2</sup> That this is one of the group of minute minerals included under the name serpentine cannot, we think, be doubted, and one of us has frequently met with both the above-mentioned varieties in Alpine serpentinous rocks which have been subjected to great mechanical disturbance.

- (b) A clear colourless mineral in granules, grains, and rather rude prismatic shapes, sometimes occurring in groups as if they were remnants of larger crystals; where these are of sufficient size and regularity for measurement, the mineral proves to be an augite and some of the grains retain traces of a cleavage, indicative of diallage.
- (c) Here and there we find grains with an orange-yellow tint, which, however, we believe, are only the same mineral stained, probably with an iron oxide.
- (d) Opaque black granules or grains, without definite shape, often more or less clustered. Examination with reflected light shows most of them to be an iron oxide, generally magnetite, but it indicates the occasional presence of a mineral, somewhat intermediate in colour between pyrite and native copper. One of us possesses,—owing to the kindness of Prof. Ulrich—a small quantity of the awaruite found in river-sands on the west coast of the South Island, New Zealand, and described by him<sup>3</sup>; and after a careful study of the two he ventures to pronounce this also to be awaruite.

The mode in which the above minerals are associated and the structure exhibited in the slices indicate beyond question that the rock has been greatly crushed, somewhat sheared, and occasionally much crumpled. Their relations one to another make it highly probable that some of the serpentinous mineral (antigorite?) has replaced augite,<sup>4</sup> but in other cases this constituent suggests an independent origin, and in one it occurs in association with the iron oxide, as in an ophitic structure. The reconsolidation of the rock since the epoch when the crushing took place seems to have been practically complete, the only macroscopic effect being a very slight schistosity. This, however, does not hold good in every part

<sup>1</sup> I find these chiefly among the larger, brighter-coloured flakes. It is possible that a small flaky hornblende may occur in the rock, but I cannot ascertain more than that some flakes extinguish at small angles.—T. G. B.

<sup>2</sup> Teall, 'British Petrography,' 1888, p. 113.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xli. (1890) p. 619. This mineral has also been described from Scandinavia and Saxony.

<sup>4</sup> My work among Alpine serpentines leads me to the conclusion (which I hope before long to set forth more fully) that the so-called 'antigorite' is more indicative of the action of severe pressure than of the former presence of augite.—T. G. B.

of the Riffelhorn, for there is some very fissile serpentine near the base of the peak on the more northern side.<sup>1</sup>

It may be interesting to note that the huge boulders near the Mattmark See, in the other branch of the Vispthal, appear to belong to the same variety of serpentine. A slice cut from a specimen collected by one of us from the smallest of the boulders agrees very closely with those described above, and it, too, contains a little awaruite.

Proceeding now to the chemical composition of the Riffelhorn rock, we come to two specimens, generally similar under the microscope, but in the one perhaps there was rather more of the bright-coloured flaky mineral than in the other, while in it awaruite was distinctly present, and a little of the pyroxene exhibited a faint brown pleochroism.

These specimens proved on analysis extremely interesting, on account of the low percentage of water compared with the amount of silica and magnesia, the practical absence of lime—of which only a trace could be detected,—and the presence of a considerable quantity of nickel: traces of copper and arsenic were also found. On first analysing the rock (from the first-named specimen), the nickel was not precipitated, but the total, as will be seen below, only added up to a little over 95 per cent.

	A.	B.
SiO <sub>2</sub> .....	40.10	40.61
$\left\{ \begin{array}{l} \text{Al}_2\text{O}_3 \\ \text{Fe}_2\text{O}_3 \\ \text{FeO} \end{array} \right\}$ .....	8.82	8.66
MgO .....	41.12	41.04
CaO .....	trace	trace
Combined water ...	4.90	4.67
Moisture .....	0.24	0.24
	<u>95.18</u>	<u>95.22</u>

An analysis was then made of a considerable quantity of the rock from the second specimen, 5 grams being taken instead of the usual 1 gram. The copper and arsenic were precipitated with sulphuretted hydrogen in acid solution; the mixed sulphides were boiled with nitric acid, and then the copper was precipitated as oxide by means of soda. The arsenic was re-precipitated as sulphide, and collected on a weighed filter. Both the copper and arsenic were present in quantities so small that great accuracy in their determination was not possible. The nickel was precipitated with soda: it was weighed as oxide of nickel. Lime was most carefully tested for with ammonium oxalate, but only a slight turbidity appeared after long standing.

The analysis was as follows:—

<sup>1</sup> See the description in Geol. Mag. 1890, p. 533.

SiO <sub>2</sub> .....	41·81
Al <sub>2</sub> O <sub>3</sub> .....	0·68
As <sub>2</sub> O <sub>3</sub> .....	0·13
Fe <sub>2</sub> O <sub>3</sub> .....	5·55
FeO .....	1·42
CuO .....	0·15
NiO .....	4·92
CaO .....	trace
MgO .....	39·86
Combined water .....	4·90
Moisture .....	0·04
	<hr/>
	99·46

The chemical analysis of the rock indicates that quite half the minerals must be anhydrous, so one at least of these—olivine, enstatite, augite, or hornblende—ought to be present. There is a group of augites and hornblendes in which the amount of lime is very small, but they generally are either altered and contain a large percentage of water, or are rich in iron and soda. The amount of iron found in this rock is, however, not much more than sufficient for the magnetite and awaruite. Anthophyllite is rich in magnesia with some ferrous oxide, but is rhombic, and most, if not all, of the pyroxenic mineral in this rock is monoclinic. But the analysis shows almost 5 % of nickel oxide, while the awaruite observed would not require so much as 1 %. Thus the nickel oxide must be largely present in one of the transparent minerals, and, since lime is only present as a trace, we infer that the anhydrous mineral is a variety of pyroxene in which lime has been replaced by oxide of nickel.<sup>1</sup>

In the hope of obtaining further proof, the rock was coarsely ground up in a mortar, and an attempt made to separate the light-coloured fragments from the darker. To obtain the former clean was comparatively easy, but the dark were generally encrusted with the lighter. The specific gravity was determined: that of the rock itself was 2·71; of the light fragments 2·68, and of the dark 3·17 (lower than one would expect, owing to their not being clean). The light portion of the rock was analysed and found to contain nickel, which again points to the presence of nickel in the pyroxenic mineral.

A third specimen was examined which also had been obtained from the summit of the Riffelhorn, at a short distance from the other two. Under the microscope it was rather less augitic than the last named, but that mineral certainly was present, though no lime (after using the test described above) was found<sup>2</sup>; nickel also was sought for and was not found. As the slice shows a grain or two of awaruite, this metal is probably present only sporadically, and not as a constituent of the pyroxene.

<sup>1</sup> [Mr. F. Rutley, since this paper was read, has kindly called my attention to a description of hydrous nickel silicates (garnierite and noumeaite) by Prof. Liversedge (Journ. & Proc. Roy. Soc. N.S.W. vol. xiv. 1880, pp. 231 *et seqq.*). Analyses of these and of nickel-magnesia silicates are given by Dana ('System of Mineralogy,' 6th ed. 1892, pp. 676, 677, 686), but all seem to differ from the above in important respects.—T. G. B.]

<sup>2</sup> The absence (virtual) of lime was confirmed by an independent analysis.

Two analyses were made, but both came out a little too high:—

	A.	B.
SiO <sub>2</sub> .....	40·27	40·25
Al <sub>2</sub> O <sub>3</sub> .....	3·96	3·26
Fe <sub>2</sub> O <sub>3</sub> .....	2·22	2·95
FeO .....	2·69	2·69
MgO .....	41·69	41·01
Na <sub>2</sub> O .....	0·71	0·71
Combined water .....	9·46	9·56
Moisture .....	0·17	0·17
	<u>101·17</u>	<u>100·60</u>

This is nearer to the analysis of an ordinary serpentine, but the amount of alumina is rather large; possibly a colourless chlorite may be present among the flaky minerals, as described in the Rauenthal serpentine.<sup>1</sup>

In conclusion, a lightning-struck rock may be noticed which was obtained by Prof. Ramsay on the Hörnli (9492 feet), a well-known point of view near the base of the Matterhorn. It is a somewhat prismatic fragment, measuring about  $1\frac{3}{4} \times 1\frac{1}{2} \times 1\frac{1}{4}$  inches. Macroscopic examination shows that it is a variety of the 'grüner schiefer' or 'green schist' of the Zermatt district, very familiar to one of us.<sup>2</sup>

As there is nothing unusual in its aspect, and the lightning-marks would be easily damaged, we have not had a slice prepared. The green mineral in this group of rocks is sometimes chlorite, sometimes a more or less actinolitic hornblende; felspar or some kindred aluminous silicate, epidote, garnet, are often—and glaucophane is occasionally—present.

On analysis a fragment of this specimen gave the following results:—

	A.	B.
SiO <sub>2</sub> .....	42·80	43·09
Al <sub>2</sub> O <sub>3</sub> .....	18·53	17·15
Fe <sub>2</sub> O <sub>3</sub> .....	7·79	7·85
FeO .....	5·01	5·93
CaO .....	11·74	12·05
MgO .....	8·96	9·04
CuO .....	trace	trace
Na <sub>2</sub> O .....	trace	trace
Combined water .....	4·71	5·10
Moisture .....	0·17	0·18
	<u>99·71</u>	<u>100·39</u>

<sup>1</sup> Wadsworth ('Lithological Studies,' pp. xxiv–xxviii) quotes 15 analyses of serpentine from nine different localities in the Alps, six of them representing specimens from the Zermatt district. In these analyses the SiO<sub>2</sub> varies from 39·7 to 42·8, the MgO from 30·1 to 41·3, and the H<sub>2</sub>O from 9·3 to 13·6. Alumina, lime, and nickel are often wanting: the maximum of the first being 2·8, of the second 4·7, of the third 0·5. Other analyses, with two of antigorite, are quoted by Teall in his interesting chapter on serpentine ('British Petrography,' pp. 113, 114).—T. G. B.

<sup>2</sup> Bonney, Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 94.



We proceed next to describe the effect of the lightning. Of the specimens before us the first was collected and given to the Museum at University College by Mr. Eccles. It is a rude slab measuring about  $9\frac{1}{2} \times 5\frac{1}{2} \times 1\frac{1}{4}$  inches, from which a large flake (also brought) has been split off, exposing a sinuous clear-drilled tube (in outline not unlike some photographs of a lightning-flash), measuring about 4 inches from end to end and terminated by outer surfaces of the fragments. It throws off a short curved side-branch, and its diameter is rather variable, but generally not more than  $\frac{1}{10}$  inch. The tube is lined with a film, hardly so thick as stout note-paper, which exhibits a minutely pitted surface. This film in the inner part of the tube is brown in colour, but it becomes black on or near the outer surfaces. Underneath it the walls of the tube appear to be quite smooth. Apertures or portions of two or three similar tubes occur on the other side of the slab.

The next specimen (represented by the second analysis, p. 455) is rudely quadrangular, measuring about  $4 \times 3 \times 1\frac{1}{4}$  inches. On both sides short tubes are seen here and there, measuring about  $\frac{1}{12}$  inch in diameter or sometimes rather less, which branch and occasionally enter the rock without, however, piercing through it. Similar wavy and branching tubes are exposed on one of the sides, which is fractured. The minor features of these tubes, so far as can be seen, are identical with the last described.

A third specimen (represented by the first analysis, p. 454) is a rudely lozenge-shaped flake, measuring about  $5\frac{1}{2} \times 3\frac{1}{2} \times 1\frac{1}{4}$  inches. On the more weathered surface we find a shallow hollow, roughly resembling an ear in shape, and about  $\frac{3}{4}$  inch long, which leads to a tube slightly oval in section and about  $\frac{1}{5}$  inch in diameter. This passes obliquely through the fragment and is exposed on the other—apparently more recently broken—surface, where it continues as a branching channel for rather more than an inch and can be traced interruptedly for about  $\frac{3}{4}$  inch farther. On one side of this, and probably connected with it, traces are found of another branching tube; the tube is lined as before with a film of a blackish glassy material, as will be described below; and patches of it can be seen on the first-named surface forming more or less branching patterns, one group being probably connected with the mouth of the tube.

The last specimen (represented by the third analysis, p. 456) is apparently a loose fragment, about  $5\frac{1}{2}$  inches in length and rudely triangular in a cross section, the longest side being about 2 inches, with weathered fawn-coloured surfaces. Neither tubes nor channels can be detected, but there are (mostly on one side) several filmy patches of the black 'pitted' glassy material, irregular in outline, two of them extending continuously for a full inch.

These fulgurites, it will be seen, bear a general resemblance to those collected by Mr. Eccles from the summit of Monte Viso and excellently described by Mr. F. Rutley,<sup>1</sup> except that in our specimens

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 60. See also, for the general aspect of the tubes, the illustration on pl. iii., where, however, the channels ramify rather more than in the cases described above.

the lining of glass is perhaps a shade thinner, and the material is a little different.

As it seemed hopeless to obtain a thin slice of the rock so as to retain a good section of the actual lining of a tube,<sup>1</sup> a little of this crust was flaked off and examined, when powdered, under the microscope. It was taken from the second of the above-named specimens. The lighter-coloured material (from the inner part of the tubes) consists of a very dark brown glass (only translucent in the very thinnest chips or edges), in which flakelets of the serpentinous mineral,<sup>2</sup> common in the rock-mass, are not infrequently embedded. The black material (external part) is similar, so far as can be ascertained, but here any approach to translucency is rare, and the above-named minerals indicate their presence only by occasionally projecting from the edges or making almost the whole-thickness of a chip.

It then occurred to us to examine the glass which could be obtained by artificial fusion of this rock. A small flake was detached from one end of the third of the above-described specimens. This was not affected by the ordinary blowpipe-flame, but was fused at the edges and on the adjacent surface by supplying oxygen instead of air; that is to say at a temperature which certainly exceeded 1700° C., or was well above the melting-point of pure iron. In this operation the thinner parts of the flake were fused and a small detached pellet—seemingly of glass,—about  $\frac{1}{12}$  inch in diameter, was obtained, but on breaking up these the former proved to be only a pellicle of glass—rarely attaining  $\frac{1}{50}$  inch in thickness, and the latter to consist of an unmelted core of rock, covered by a film of glass varying from about  $\frac{1}{100}$  to  $\frac{1}{50}$  inch. This glass also was of a very dark brown colour, and its surface was slightly pitted with minute depressions; in fact it was practically identical with that which had been produced by the lightning. Samples from each were crushed, mounted,<sup>3</sup> and examined under the microscope with various magnifications up to about 400. The glass, so far as can be seen, does not differ in any respect from that produced by the lightning. Only the thinnest parts are translucent, and these are of a deep umber-brown colour, like the darkest varieties of tachylyte. As in the other case it includes flake-like minerals, between which it can be seen, as it were, to penetrate, so that a transitional zone separates that of complete fusion from the unfused rock, both of these zones being very narrow. In the first-named many mineral

<sup>1</sup> One of the slices had accidentally intersected a tube, but nothing satisfactory could be made out from the fragments of fused material that still adhered. It does, however, indicate that the minerals immediately below the glass assume, for a very short distance, a cloudy aspect, due, so far as can be seen, to the development of extremely minute cavities, sometimes tubular.—T. G. B.

<sup>2</sup> I contrived to measure the extinction in some; generally it was straight, but in one or two cases it appears to be slightly oblique. Both tints (mentioned already) were noted.—T. G. B.

<sup>3</sup> I am indebted to Miss C. A. Raisin, B.Sc., for preparing the slides of glass used in this paper, and for independently examining them so as to verify my results.—T. G. B.

flakes occur, more or less prismatic in outline: these usually give straight extinction and fairly high polarization-tints. Probably they are antigorite. The other constituent (or constituents) has evidently proved more fusible,<sup>1</sup> so that a structure imitating that called ophitic has been produced. In some cases the fused part exists as minute specks or granular patches, or it forms streaks, which are either 'knobby' or irregular, or like fibres with forked ends. Both these products seem to follow cleavage-planes, and the latter present a tubular aspect, but as the threads are so minute (less than  $\frac{1}{2500}$  inch in diameter) it is difficult to be sure of this matter.

A little of the brown glass, spattered on the 'green schist' from the Hörnli, has been examined in like way: the chips of this are in all important respects so similar to the glass described and figured by Mr. Rutley in his account of the Monte Viso fulgurites that no further description of its characters is necessary.

The extreme thinness of the slaggy crust, the smoothness of the underlying surface of the tube, and the rapid passage from the one to the other in the case of the serpentine, are remarkable. These tubes look as if they had been drilled with a fine boring-tool, and afterwards coated with a viscous or 'slaggy' varnish, in the making of which only the more fusible parts of the rock have been melted. The holes themselves, except for their sinuous course, remind one on a small scale of the perforation made by a rifle-bullet in a rather soft material, or that driven through a steel armour-plate by the bolt from a large cannon. The material thus removed appears for the most part to have been blown away to some distance, for we do not find it deposited at the mouth of the orifice.

#### DISCUSSION.

Prof. RAMSAY mentioned that, a few days before the visit of Mr. Eccles and himself to the Riffelhorn, they had spent a considerable time on the Gorner Glacier, watching the lightning striking the Riffelhorn. It is not improbable that the fulgurites found were formed on this occasion. He mentioned a fulgurite which he had found in 1891 on the summit of Cir Mhor in Arran, in which a slab, a segment of a sphere, nearly a yard in diameter, had been dislodged from one of the blocks of granite of which the hill consists. The granite was glazed, as was also the dislodged slab. He had visited the spot every year since, and at present all trace of glaze has disappeared, owing to the weathering of the rock. He also remarked on the probability of the presence of arsenide of nickel in the rock.

Mr. RUTLEY commented on associations of nickel with serpentine. The percentage of nickel oxide shown in the analysis was very high, compared with the amounts, seldom reaching 1 per cent., in

<sup>1</sup> I think that, in both the natural and the artificial fusings, the dark glass is formed by the melting together of the granules of augite and of iron oxide, and the serpentinous minerals have proved more refractory.—T. G. B.

analyses of serpentines from North Carolina and elsewhere. Mr. Eccles had informed him that the fulgurites described in the paper did not appear to penetrate the rock to any great depth, and that they seemed ultimately to branch and thin off. This accorded with observations which he had already made concerning the probable terminations of certain fulgurites of the sand-tube type. He alluded to an exceptional case, in which a few crystallites were present in fulgurite-glass. In all other cases with which he was acquainted such glass showed no inclusions other than gas-pores. Miss Aston's analysis was one of considerable value and interest. So far as he knew, this was the only recorded case of the occurrence of fulgurites in serpentine.

Dr. PRELLER, having witnessed the effects of violent lightning-discharges in various parts of the Alps, observed that mountain-peaks, such as the Riffelhorn and Monte Viso, in which occurred serpentine or other magnetite-bearing rocks, appeared to be subject more especially to direct lightning-discharges, producing perforations similar to those described by Prof. Bonney and Mr. Rutley; while limestone peaks, such as the Stanserhorn near the Lake of Lucerne, and Mont Salève near Geneva, appeared to be more frequently struck by indirect, that is, meandering or side discharges. He quoted a specific case which occurred within his knowledge on the Stanserhorn two years ago, when an indirect discharge only left black marks on going to earth through the electric installation erected on the lower of the two limestone peaks. He thought that abundant evidence of the effects of atmospheric electricity upon rocks would be found in the Western Islands of Scotland, which, being chiefly basaltic, contained a large percentage of magnetic iron, and which Profs. Rücker and Thorpe had shown to lie in a magnetic zone.

Mr. ECCLES also spoke.

Prof. BONNEY thanked the Fellows for the reception which they had given to the paper, and said that it was quite true that some nickel was generally found in a serpentine, but that, so far as he could ascertain, anything like 4.9 per cent. was exceptional.

23. *NOTES concerning certain LINEAR MARKS in a SEDIMENTARY ROCK.*

By Prof. J. E. TALMAGE, D.Sc., F.G.S. (Read March 11th, 1896.)

[Abstract.]

THE marks described in the paper occur in a fine-grained argillaceous sandstone referred by the U.S. Geological Survey to the Triassic or Jura-Trias period, which is found on a low tableland within 2 miles of the bluffs overlooking Glen Canyon. The marks commonly appear as straight lines intersecting at right angles, but some have a pinnate distribution, suggesting engravings of frost-flowers. A description of the markings is given, and various experiments made in the laboratory to illustrate the effects of formation of crystals formed over sediment are described. (See a paper by the same Author in the Utah University Quarterly for December 1895.)

24. *The GYPSUM DEPOSITS of NOTTINGHAMSHIRE and DERBYSHIRE.*

By A. T. METCALFE, Esq., F.G.S. (Read January 8th, 1896.)

[Abstract.]

THE gypsum deposits of these counties occur in the Upper Marls of the Keuper division of the Triassic system. The author describes their occurrence in thick nodular irregular beds, large spheroidal masses, and lenticular intercalations, and their association with satin-spar, alabaster, selenite, and anhydrite.

25. *CONTRIBUTIONS to the STRATIGRAPHY and PALÆONTOLOGY of the*

*GLOBIGERINA-LIMESTONES of the MALTESE ISLANDS.* By J. H. COOKE, Esq., F.L.S., F.G.S. (Read April 15th, 1896.)

[Abstract.]

A BIBLIOGRAPHY of the *Globigerina*-limestones is followed by some remarks on the physical features and general distribution of the strata. The limestones are divided into nine subdivisions, lettered A to I, the former being uppermost. Four seams of phosphatic nodules form the subdivisions B, D, G, and I, and local nodule-bands also occur in E. The subdivision G serves as a line of demarcation between the Langhian Series (Miocene) and the Aquitanian (Oligocene). Details of the lithological and palæontological characters of the various subdivisions are given, and the Author concludes that I and the lower part of H were laid down on a sinking sea-floor, in about 300 fathoms of water; that the upper

part of H and G, F, E, D, composed to a large extent of *Globigerina* and other pelagic organisms, were probably deposited in about 1000 fathoms; while C, B, and A were probably laid down, like I and the lower part of H, in about 300 fathoms of water.

#### DISCUSSION.

Dr. J. W. GREGORY expressed his appreciation of the work done by the Author in zonal collecting from Malta. He was glad to find that his detailed collections supported the correlation and classification of the Maltese rocks which the speaker had suggested from the study of the Echinoidea.

Dr. WOODWARD expressed regret that he had not arranged to send up from the British Museum (Natural History) a series of specimens left with him in illustration of this paper. He bore testimony to the great labour which the Author had expended in conducting the researches on the *Globigerina*-limestones of Malta, to the working out of which he had been urged by Dr. John Murray. The Author had not only laboured to perfect the palæontology, but had also had several analyses made by chemists to strengthen the evidence in his paper.

26. *On a PHOSPHATIC CHALK with HOLASTER PLANUS at LEWES.* By A. STRAHAN, Esq., M.A., F.G.S. *With an APPENDIX on the FORAMINIFERA and OSTRACODA.* By F. CHAPMAN, Esq., A.L.S., F.R.M.S. (Communicated by permission of the Director-General of H.M. Geological Survey. Read March 25th, 1896.)

IN 1891 I described before this Society a phosphatic chalk which occurred near the top of the Upper Chalk of Taplow, and resembled the deposits long known and worked in Belgium and the North of France, but not up to that time recognized in this country.<sup>1</sup> Up to the present, in spite of much searching, no other occurrence of this rock has been recorded in England, but during the summer of 1895 Mr. John Rhodes, fossil collector to the Geological Survey, while engaged in collecting from the great chalk-pits near Lewes, noticed a thin band bearing a strong resemblance to the Taplow phosphatic chalk. At the request of the Director-General I visited the spot and made the following notes.

The pit, which is marked on the 6-inch and 1-inch (new series) Ordnance maps as the Southerham Pit, lies on the south-western side of the high downs of Upper Chalk which overlook Lewes from the east. A somewhat marked syncline traverses the central part of these hills in an east-and-west direction. Thus Lewes, situated nearly on the synclinal axis, stands on Upper Chalk, but both to the north and south of the Downs the Middle and Lower Chalk emerge with southerly and northerly dips respectively. The Southerham Pit extends from the Middle to high up in the Upper Chalk, but the workings in the Middle Chalk have been abandoned and are partly obscured. A small bank, however, at the eastern end of the long line of limekilns affords a good view of the junction of the Upper and Middle subdivisions and of the phosphatic band in question. Though only about 20 yards in length, the cutting suffices to show the impersistent character of the deposit. To illustrate this I give three sections taken at intervals of about 10 yards.

*About the middle of the Cutting.*

	ft.	ins.
Massive chalk with flints.		
Flaky white chalk with a few flints and <i>Holaster planus</i> ...	4	0
passing down into		
Phosphatic chalk with many small fish-teeth, a few spines of <i>Cidaris</i> and some nodules, partly green, partly brown, up to 1½ inch in diameter .....	1	6
A sharp line of demarcation.		
Hard creamy limestone with calcite in veins and cavities, nodular (some of the nodules being green-coated), lumps of decomposed iron-pyrites .....	1	6
Hard, white, compact chalk, traversed by branching pipes and thin laminae of phosphatic chalk .....	3	0
Hard, white, compact chalk, with the pipes and laminae of phosphatic chalk less abundant and dying away downward.	3	0

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 356; see also 'Natural Science,' vol. i. no. 4, p. 284, and Geol. Mag. 1895, p. 336.

*Ten yards west of the above.*

Massive chalk with flints, some paramoudra.	ft.	ins.
Flaky chalk with few flints .....	4	0
passing down into		
Phosphatic chalk, poor in phosphatic grains .....	1	0
Phosphatic chalk, richer .....	1	4
Hard creamy nodular limestone, as above.		

*Ten yards east of the first Section.*

Flaky chalk with flints, a very few phosphatic grains at the base. A small, nearly spherical flint, 2 inches from the base, contained some grains .....		
Hard nodular limestone, as above .....	1	0
Hard white chalk, piped with phosphatic chalk, as above. ...	3	0

The hard nodular limestone referred to in the above sections not only resembles the Chalk Rock, but occurs at the horizon assigned to that stratum on stratigraphical evidence. The fossils collected by Rhodes confirm this view. Specimens from the Upper Chalk worked in the northern part of the pit included, according to the identification of Mr. Sharman, the following forms:—

<i>Ventriculites decurrens.</i>	<i>Crisina.</i>
<i>Serpula ilium.</i>	<i>Entalophora.</i>
<i>Cidaris-spine.</i>	<i>Rhynchonella Mantelliana.</i>
" <i>clavigera-spine.</i>	" <i>plicatilis.</i>
<i>Bourgueticrinus.</i>	<i>Terebratula semiglobosa.</i>
<i>Echinocorys vulgaris.</i>	<i>Terebratulina gracilis.</i>
<i>Micraster cor-bovis.</i>	" <i>striata.</i>
" <i>cor-testudinarium.</i>	<i>Inoceramus Cuvieri?</i>
<i>Salenia.</i>	<i>Lima spinosa.</i>

The beds assigned to the Chalk Rock contained:—

<i>Cidaris-spines.</i>	<i>Terebratula semiglobosa.</i>
<i>Holaster planus</i> , Mant. (about 4 feet above the phosphatic band).	<i>Terebratulina gracilis.</i>

In the phosphatic band fish-remains abounded, both minute pellets and teeth. Among the latter Mr. E. T. Newton, F.R.S., identified:—

<i>Corax falcatus.</i>	<i>Oxyrhina</i> (a tooth about $\frac{3}{4}$ inch long).
<i>Odontaspis.</i>	

An exposure of the Middle Chalk a few yards south of the out-crop of the Chalk Rock yielded:—

<i>Ventriculites.</i>	<i>Spondylus striatus.</i>
<i>Lima spinosa.</i>	Fish-remains.
<i>Ostrea Normaniana.</i>	

While the lowest beds seen in the pit contained:—

<i>Rhynchonella Cuvieri.</i>	<i>Inoceramus mytiloides.</i>
<i>Terebratula semiglobosa.</i>	



The whole exposure therefore ranges from the *Micraster*-zones of the Upper Chalk to the *Rhynchonella Cuvieri*-zone of the Middle Chalk inclusive, and the brown chalk may be referred with certainty to the horizon of the Chalk Rock. In this respect alone it differs from the phosphatic chalk of Taplow, which occurred in the zone of *Belemnitella quadrata*, 20 feet only below the base of the Tertiary deposits of that neighbourhood.

The Southerham phosphatic chalk resembles that of Taplow so closely in composition that its description may be dismissed in a few words. It consists of a white chalky matrix in which are embedded a multitude of brown grains. In weathered specimens these grains can be washed out in water, but the separation can be better effected by dilute acetic acid, which removes almost all the matrix, but scarcely corrodes the brown grains. Mr. Player, to whom I was indebted for the chemical examination of the Taplow Chalk, confirmed my opinion that the brown grains from Southerham also consist largely of phosphate of lime. They resemble those of the Taplow Chalk so nearly that he did not consider it necessary to make a full analysis. The Taplow grains were found by him to contain 50·6 per cent. of phosphate of lime, while the rock in its raw state contained 18 to 35 per cent.<sup>1</sup> The Southerham brown chalk in the raw state is probably rather less rich than the Taplow material, and this, taken in connexion with the fact that it is thin and impersistent, seems likely to preclude it from proving of economic value.

The microscope also shows a complete resemblance between the residue of the Southerham and Taplow chalks, after treatment with acetic acid. In the former the oval pellets which were determined as the coprolites of small fishes are rather more abundant and larger, but proportionate in size to the numerous teeth which occur. The prisms of *Inoceramus*-shell are rather less common, but internal casts of foraminifera form a large proportion of the residues, and small amber-coloured chips of bone occur equally in both. A thin slice of the raw rock shows the clear shells of the foraminifera surrounding the internal phosphatic casts.<sup>2</sup> The reactions with polarized light are the same in both rocks. When treated with hydrochloric acid some of the foraminifera are seen to have been filled with a greenish mineral resembling glauconite, the proportion so filled being rather larger in the Southerham than in the Taplow Chalk, especially in the greenish nodules which occur in the phosphatic band. Further details of either chemical or microscopical examination of the rock would be a mere repetition of the account of the Taplow Chalk given in this Journal (vol. xlvii. 1891, pp. 358-362).

The flint referred to in the third section as occurring 2 inches above the rocky floor is seen under the microscope to contain many

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 358.

<sup>2</sup> Pl. xx. fig. 2 in 'Deep Sea Deposits' (*Challenger Reports*) shows recent foraminifera from a depth of 1900 fathoms similarly infiltrated. The illustration closely represents the appearance of the organisms of the phosphatic chalk.

foraminifera, silicified, and not easily distinguishable from the matrix. Some, however, have been filled with a brown mineral resembling the phosphate of the phosphatic chalk; in such the shell only has been silicified, the carbonate having been replaced more readily than the phosphate of lime, as might have been expected.

The existence of these two stratigraphically distinct deposits throws additional light on the origin of phosphatic chalks generally, for it enables us to select with greater certainty the phenomena which accompany the formation of such a rock. The characteristics which are common to both may be enumerated as follows:—

1. The abundance of organic remains (pellets, teeth, and bone-fragments), which originally contained phosphate of lime.
2. The phosphatization of organisms (foraminifera and shell-prisms) which were originally composed of carbonate of lime.
3. The impersistent character of the deposits.
4. The association of the deposits with a floor of hard nodular chalk.
5. The perforation of the white chalk beneath this floor by branching tubes filled with phosphatic chalk.

1, 2, & 3. On the first two of these points I dwell at some length in my former paper; the impersistent character of the deposits which was suggested by the non-appearance of the Taplow phosphatic Chalk elsewhere seems now to be confirmed by the fact that the Southerham Chalk thins away or passes into ordinary white chalk within a few yards. The Continental deposits, moreover, which have been extensively worked, form lenticles rarely exceeding 1 kilometre in length and about 200 or 300 metres in breadth.

4. But the association of the deposit with a hard floor and the perforation of the chalk beneath by tubes filled with phosphatic chalk acquire some significance from being repeated in a different locality and at a different horizon.

Such floors are far from uncommon. One of the best known and most extensive is that known as the Chalk Rock, but they occur also at all horizons in the Upper and Middle Chalk. They are specially characterized by an unusual hardness and a nodular or lumpy structure; by the presence of glauconite either as casts of microscopic organisms or as coating the nodules; and by a slight increase in the proportion of phosphate of lime either disseminated through the rock or filling the small organisms.

The unusual hardness of the floors on which the phosphatic chalks of Taplow and Southerham rest suggested partial phosphatization of the rock. This, however, was disproved by an analysis by Mr. Player which showed the presence of only a very small quantity of phosphoric acid; nor was silica or magnesia present in sufficient quantity to account for the character of the rock, the composition of which, in fact, scarcely differs from that of ordinary chalk.

The existence of calcite in veins and cavities is an unusual feature, and suggested that the hardness might be due to a crystalline

cement. Under the microscope, however, the rock is seen to consist of an amorphous calcareous paste, enclosing numerous foraminifera, though not nearly in such abundance as the phosphatic chalk. The foraminifera, many of which are perfect, are filled with the same material as that which forms the matrix. No foreign minerals were observed.

In spite of the negative character of the microscopic evidence, it seemed not unlikely that the replacement of the carbonate of lime (in the organisms which were originally calcareous) by an acid phosphate had set free carbonic acid, and led to the production of a soluble bicarbonate of lime. A solution of this coming into contact with the underlying and less permeable white chalk might have hardened it by infiltration, and might explain also the existence of the calcite in the joints and cavities.

But it must be remembered that the association of phosphatic chalk with these floors is the exception and not the rule. Though the hardened chalk underlies the phosphatic chalk in both the English sections, and in some of the Continental occurrences also, in the great majority of cases these rock-bands are overlain by white chalk of the normal character. Their lumpy and nodular structure seems then to suggest a concretionary action, probably accompanying a pause or change in the sedimentation; that the action was contemporaneous is proved by the fact that small organisms not unfrequently adhere to the nodules.<sup>1</sup>

Before quitting the subject I should mention that in the Chalk Rock there is evidence of something more than a mere change in the sedimentation. It has long been known that the fauna of this horizon is peculiar, especially on account of the presence of certain gasteropoda; foreign detritus, moreover, becomes more abundant in this band than elsewhere in the Upper Chalk. Dr. Hume, as a result of an exhaustive examination of the residues and conditions of deposit of the Chalk, concludes that 'lithological evidence points to the close of the Middle Chalk period as having been a time of change, probably in the direction of re-elevation. The palæontological facts seem peculiarly striking in this respect.' *Holaster*, *Ammonites*, and *Scaphites*, which were last met with in abundance in the Grey Chalk, return in the Chalk Rock, and the arenaceous foraminifera, the abundant quartz-grains from the residues, the crystals of tourmaline, were all left behind in the Grey Chalk, but reappear in the Chalk Rock. He shows, too, that the other mollusca also were affected. '*Turbo gemmatus* and forms of *Trochus* and *Solarium* again resume their place among the important fossils of this series. The trochoid forms are the last to disappear during depression, and they are also the first to reappear during elevation.'<sup>2</sup>

<sup>1</sup> Hill & Jukes-Browne, Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 230; see also 'Geology of the Isle of Wight,' 2nd ed. Geol. Surv. Mem. 1889, pp. 78, 79.

<sup>2</sup> 'Ocean Deposits, Ancient and Modern,' by W. F. Hume, 'Natural Science,' vol. vii. (1895) p. 390; and 'Chemical and Micro-Mineralogical Researches on the Upper Cretaceous Zones of the South of England,' 1893.

Without, perhaps, inferring actual re-elevation on this evidence, I should so far agree with Dr. Hume that the rock has originated in a decided, though temporary, change in the conditions under which the Chalk was being deposited. To suppose a change to have taken place in the strength or direction of the local currents seems less violent than to assume a reversal of the movement of the earth's crust.

The glauconite and phosphate of lime occur in the form and position in which they were deposited, for a large proportion of both fills the interior of more or less perfect foraminifera. In this respect the glauconite differs from that found in the Greensands, where it occurs as loose grains seldom enclosed in their original moulds and generally with an appearance of having been corroded. Both minerals, as shown in the *Challenger* Reports ('Deep Sea Deposits,' pp. 382, 383), are being formed on the sea-bottom at the present day, and in constant association. Glauconite appears in its most typical form and greatest abundance along high and bold coasts where no rivers enter the sea and where accumulation is not rapid. Between 200 and 300 fathoms it is more abundant than in deeper water, and though glauconitic casts have been met with at depths of over 2000 fathoms, they are stated never to occur in truly pelagic deposits (*op. cit.* p. 396). Its occurrence, therefore, in the phosphatic chalk indicates a comparatively shallow-water origin for the rock. The foraminifera, though, as shown by Mr. Chapman in the appendix, indicating a deeper-water origin for the Southerham than for the Taplow phosphatic chalk, support this inference, while the mode of occurrence of the phosphate points in the same direction, for the source of the phosphoric acid seems undoubtedly to lie in the remains of fish which lived on the spot, and which are unlikely to have been inhabitants of the deeper part of the ocean. This accords also with the view that has been suggested by what we know of the limits of the Chalk-sea, namely, that no part of the English Chalk was formed far from land, and presumably, therefore, none in any great depth of water.<sup>1</sup> We may perhaps infer with some probability that the Southerham phosphatic chalk was formed at a depth of between 200 and 600 fathoms.

In the same volume ('Deep Sea Deposits,' pp. 396, 397) it is pointed out 'that phosphatic nodules are apparently more abundant in deposits along coasts where there are great and rapid changes of temperature, arising from the meeting of warm and cold currents. . . . It seems highly probable that in these places large numbers of pelagic organisms are frequently killed by these changes of temperature, and may in some cases form a considerable layer of decomposing matter on the bottom of the ocean.' The same thing is stated to occur where large quantities of fresh water are thrown into salt water by floods.

The facts observable in connexion with the phosphatic chalk

<sup>1</sup> On this subject see also 'On the Microscopic Structure of the Zones of the Chalk,' by A. J. Jukes-Browne, *Proc. Yorks. Geol. & Pol. Soc.* vol. xii. part v. (1894).

seem only in part reconcilable with such a theory as the above, as to its origin. The rocky floors mark the pause or interruption in the sedimentation caused by the change of current, while the probably accompanying change of temperature would help in explaining the presence of the glauconite and phosphates. On the other hand, it should be remembered that the phosphatic deposits bear internal evidence, in the shape of the abundant excreta, of having been a feeding-ground rather than a burial-place.

5. On the fifth point of resemblance between the Taplow and Southerham sections, namely, the perforation of the underlying white chalk by branching tubes filled with the phosphatized variety, I have found little to throw any additional light. The tubes are rounded, and, being filled with a material markedly different from the surrounding rock, are well-defined.<sup>1</sup> The phosphatic chalk in these exactly resembles that of the phosphatic stratum itself; it, moreover, spreads here and there for a few inches along planes of current-bedding in the white chalk. The tubes range up to an inch in diameter and run vertically as often as in any other direction; they branch frequently and irregularly.

These tubes perhaps approach '*Spongia paradoxa*' more nearly than any other structure with which I am acquainted, except in being generally smaller. The origin of this so-called organism remains doubtful after much discussion. Prof. Hughes has argued in favour of the structure being wholly concretionary<sup>2</sup>; but in the present case, where there is a marked difference between the contents of the tube and the surrounding rock, his arguments would not apply. It seems necessary to suppose that the tubes existed as such, and were open, and that phosphatized organisms were being occasionally washed about, while the white chalk was being deposited. Against their being the borings of molluscs,<sup>3</sup> or casts of the hollows left by seaweeds or annelids, various objections may be urged, and on the whole Zittel's supposition with respect to '*Spongia paradoxa*,' that it is the cast of a horny sponge, seems the most applicable in the present case also.

#### CONCLUSIONS.

The close resemblance of the Southerham chalk, at the base of the Upper Chalk, to the Taplow chalk, at the top of that formation, indicates that the conditions under which such a deposit was formed were not confined to any one zone. They may probably have recurred at any horizon in the Chalk.

The conclusion formed with regard to the Taplow phosphatic

<sup>1</sup> A thin section across one of the tubes and the surrounding matrix was described in my former paper, Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 358.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xl. (1884) p. 276 and discussion.

<sup>3</sup> M. de Mercey, in describing a nodular chalk which forms the top of the *Micraster*-zone, speaks of it as being sometimes pierced by *Pholades*. Numerous tubular pores penetrate it deeply. Bull. Soc. Géol. France, ser. 2, vol. xx. (1863) p. 635.

chalk, that the concentration of the phosphoric acid was the work of small fishes, is strengthened by the fact that the remains of such animals are still more abundant in the Southerham chalk.

The deposits seem to have some connexion with hard nodular floors which are believed to mark changes or pauses in the sedimentation, accompanied by contemporaneous concretionary action. Though presenting points of similarity with phosphatized *Globigerina*-ooze, they are not pelagic deposits.<sup>1</sup>

The same cause which delayed the sedimentation (whether change of current or otherwise) seems occasionally to have led to the assembling of multitudes of small fishes, but rather by providing them with food than by causing their destruction.

#### APPENDIX BY F. CHAPMAN, Esq., A.L.S., F.R.M.S.

##### THE FORAMINIFERA AND OSTRACODA.

The following notes and accompanying list are the result of an examination—(1) of some unweathered phosphatic chalk, which was crushed and levigated; (2) of about fifteen mounts of specimens selected by Mr. J. Bennie, together with other specimens which I obtained from similar material, and which had been taken from a weathered surface of the same phosphatic band.

The foraminifera and ostracoda from each of the samples differed so materially from one another in their general facies that it seemed advisable to keep the two lists separate. One noteworthy difference is the occurrence of six species of ostracoda in sample 2, and only one species in sample 1. There is also a predominance of arenaceous forms in sample 1, mainly belonging to the Textulariidae; while the members of the Lagenidae largely obtain in sample 2. This latter, along with the occurrence of the ostracoda, points to the shallower condition of the water for sample 2.

The foraminifera are, with few exceptions, either entirely phosphatized, or they are infilled with phosphate of lime. This is clearly seen by examining material which has been treated with weak acetic acid, some of the specimens retaining their usual outline and superficial markings, while others are represented only by the form of the chamber-cavities of the shell, and have the delicate stolon-passages preserved in relief by the infilling process.

The foraminiferal facies of the Southerham chalk appears to differ very essentially from that of the phosphatic chalk of Taplow,<sup>2</sup> but it agrees exactly with the fact of its being on a lower horizon than the latter rock, since there is a noticeable scarcity of truly Upper Chalk forms in the material under discussion.

Forty-two species and varieties of foraminifera and six species of

<sup>1</sup> [In reading the paper I used here the expression 'shallow water' in place of 'not pelagic.' This did not, however, convey the meaning I intended, and led to an apparent difference of opinion in the discussion.—May 15th, 1896.]

<sup>2</sup> F. Chapman, Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 514.

ostracoda are here recorded from the chalk of Southerham. The ostracoda are all known from the Chalk.

As regards the foraminifera, only 57 per cent. of the forms from Southerham are found at Taplow; and, from the evidence afforded by a comparison of the two faunas, that of the Southerham chalk seems to be of deeper-water origin than the one from Taplow.

The family of the Miliolidae is represented in the Taplow chalk by no less than seven species, while only a doubtful glauconite-cast of a *Miliolina* has been collected from the Southerham chalk.

The family of the Lituolidae is represented in the Southerham chalk by two species of *Haplophragmium*, the Taplow chalk yielding no example.

The next family—the Textulariidae—is one of the best represented in the Southerham chalk, and comprises *Textularia* (3 forms), *Tritaxia* (3), *Spiroplecta* (1), *Gaudryina* (3), and *Bulimina* (5). The species are represented in the Taplow chalk, with the exceptions of *Tritaxia pyramidata*, Reuss (also abundant in the Chalk Marl and Gault), *Gaudryina pupoides*, d'Orb., *Bulimina polystropha*, Reuss, and *B. pupoides*, d'Orb. The siphonate *Tritaxia*, *T. foveolata*, Marsson, was also found in the Taplow chalk, but not recorded, and I am indebted to Mr. F. W. Millett for directing my attention to its occurrence there.

The family of the Lagenidae, while it is fairly well represented in the Southerham chalk by some genera, is conspicuously poor in those having delicate tests such as *Lagena*, *Lingulina*, *Fronicularia*, and *Polymorphina*, all of which are recorded from the Taplow chalk. It is possible that examples of genera such as these may have been destroyed by subsequent disturbances of the deposit; but it is, perhaps, more probable that their absence may be accounted for by the bathymetrical conditions, seeing that these genera are usually found in fairly shallow water.

Of the Globigerinidae, *Globigerina æquilateralis*, Brady, is conspicuously rare in the Chalk of Southerham.

The Rotaliidae are remarkably few in number, being represented by five genera only, with as many species. By far the most interesting form in this family from the Southerham chalk is *Gypsina cretae* (Marsson).<sup>1</sup> The species is here recorded for the first time from the English Chalk, and was described by Dr. Marsson from the White Chalk of Rügen.

See full lists on next page.

In concluding these notes I wish to express my obligations to Prof. J. W. Judd, C.B., LL.D., F.R.S., who very kindly gave me facilities for working out these results in the Geological Laboratory of the Royal College of Science.

<sup>1</sup> *Acervulina cretae*, Marsson, 1878, Mitth. Nat. Ver. Neu-Vorpommern u. Rügen, vol. x. p. 171, pl. v. fig. 39 a & b.

FORAMINIFERA.

No.	Name.	Sample No. 1.	Sample No. 2.
1.	? <i>Miliolina seminulum</i> (L.) .....	1 specimen.	
2.	<i>Haplophragmium irregulare</i> (Röm.) ...	.....	1 specimen.
3.	" <i>ovatum</i> (Hag.) .....	.....	1 specimen.
4.	<i>Textularia globulosa</i> , Ehr. ....	frequent.	
5.	"      " <i>var. striata</i> (Ehr.) .....	frequent.	
6.	" <i>trochus</i> , d'Orb. ....	1 specimen.	1 specimen.
7.	<i>Tritaxia tricarinata</i> , Reuss .....	1 specimen.	rare.
8.	" <i>pyramidata</i> , Reuss .....	frequent.	frequent.
9.	" <i>foveolata</i> , Marsson .....	rare.	
10.	<i>Spiroplecta annectens</i> (P. & J.) .....	frequent.	1 specimen.
11.	<i>Gaudryina rugosa</i> , d'Orb. ....	rare.	
12.	" <i>pupoides</i> , d'Orb. ....	common.	1 specimen.
13.	" <i>Jonesiana</i> , Wright .....	1 specimen.	
14.	<i>Bulimina polystropha</i> , Reuss .....	.....	1 specimen.
15.	" <i>obtusa</i> , d'Orb. ....	frequent.	
16.	" <i>pupoides</i> , d'Orb. ....	1 specimen.	
17.	" <i>Murchisoniana</i> , d'Orb. ....	1 specimen.	
18.	" <i>affinis</i> , d'Orb. ....	rare.	
19.	<i>Nodosaria consobrina</i> , d'Orb. ....	.....	rare.
20.	" <i>communis</i> , d'Orb. ....	1 specimen.	
21.	<i>Rhabdogonium tricarinatum</i> , <i>var. acut-</i> <i>angulum</i> , Reuss .....	.....	1 specimen.
22.	<i>Marginulina æquivoca</i> , Reuss .....	.....	1 specimen.
23.	<i>Vaginulina recta</i> , Reuss .....	.....	1 specimen.
24.	<i>Cristellaria cultrata</i> (Montf.) .....	frequent.	common.
25.	" <i>rotulata</i> (Lam.) .....	common.	common.
26.	" <i>gaultina</i> , Berth. ....	.....	rare.
27.	" <i>navicula</i> , d'Orb. ....	.....	1 specimen.
28.	" <i>acutauricularis</i> (F. & M.) ..	.....	1 specimen.
29.	" <i>gibba</i> , d'Orb. ....	1 specimen.	frequent.
30.	? <i>Flabellina</i> , sp. ....	.....	fragment.
31.	<i>Polymorphina æquiformis</i> (Römer) .....	.....	1 specimen.
32.	<i>Ramulina aculeata</i> , Wright .....	.....	rare.
33.	" <i>levis</i> , Jones .....	1 specimen.	1 specimen.
34.	<i>Globigerina cretacea</i> , d'Orb. ....	common.	frequent.
35.	" <i>marginata</i> (Reuss) .....	very common.	common.
36.	" <i>bulloides</i> , d'Orb. ....	rare.	
37.	" <i>æquilateralis</i> , Brady .....	1 specimen.	
38.	<i>Discorbina Bertheloti</i> (d'Orb.) .....	1 specimen.	
39.	<i>Anomalina ammonoides</i> (Reuss) .....	very common.	very common.
40.	? <i>Pulvinulina elegans</i> (d'Orb.) .....	1 specimen.	
41.	<i>Rotalia Soldanii</i> , d'Orb. ....	common.	
42.	<i>Gypsina cretæ</i> , Marsson .....	1 specimen.	

OSTRACODA.

No.	Name.	Sample No. 1.	Sample No. 2.
1.	<i>Bairdia subdeltoidea</i> (Münster) .....	.....	frequent.
2.	<i>Cythereis auriculata</i> (Cornuel) .....	.....	1 specimen.
3.	" <i>ornatissima</i> , Reuss, <i>var. pau-</i> <i>pera</i> , J. & H. ....	.....	1 specimen.
4.	<i>Cytherella Muensteri</i> (Röm.) .....	1 specimen.	common.
5.	" <i>ovata</i> , (Röm.) .....	.....	very common.
6.	" <i>obovata</i> , J. & H. ....	.....	1 specimen.



## DISCUSSION.

Dr. W. F. HUME remarked that it is notable that the phosphatic chalks in England are not only so rare, but are also connected with nodular conditions. The Middle Chalk in the South-East of England has usually two prominent zones of nodular character—one at the base, the Melbourn Rock; the other at the summit, the Chalk Rock. Between these the chalk is fine-grained, and only contains minute fossils. At Lewes, however, the conditions are somewhat different, the nodular conditions being several times repeated, while pebbles, fragments of wood, large *Inocerami* and *Ammonites*, all suggest the possibility of current-conditions at this particular locality. It is therefore particularly interesting to find the phosphatic chalk here. It is also noticeable that the foraminiferal fauna, as mentioned by Mr. Chapman, has here a deeper aspect than that at Taplow, the same statement holding good when compared with the Lower Chalk foraminifera.

Dr. G. J. HINDE could confirm the very close resemblance of the Lewes phosphatic chalk to that of Taplow. He did not agree with the Author in considering the deposit of shallow-water origin, for microscopic sections showed that the rock was a purely organic deposit without admixture of clastic materials; it was, in fact, similar in its constituents to a *Globigerina*-ooze, and was probably formed under much the same conditions of depth as this latter.

The AUTHOR was interested in hearing from Dr. Hume of an abnormal character in the Chalk near Lewes; such observations tended to throw light on the origin of phosphatic chalk. His inference as to the shallow-water origin of the deposit was founded on observations made in the *Challenger* Reports on the formation of glauconite and phosphate. He agreed with Dr. Hinde as to the absence or great scarcity of clastic material. The term 'shallow water' required definition: by it he meant any depth between 200 and 600 fathoms. Undoubtedly the phosphatic chalk strongly resembled *Globigerina*-ooze, in fact the plate in the *Challenger* Reports illustrating phosphatized ooze would serve also for phosphatic chalk; but in the latter glauconite has been formed in some abundance, and we learn from the *Challenger* Reports that this mineral is not now being formed in truly pelagic deposits, such as the *Globigerina*-ooze.

27. *On SUBMERGED LAND-SURFACES at BARRY, GLAMORGANSHIRE.*  
By A. STRAHAN, Esq., M.A., F.G.S. *With NOTES on the FAUNA and FLORA* by CLEMENT REID, Esq., F.L.S., F.G.S.; and an *APPENDIX on the MICROZOA* by Prof. T. R. JONES, F.R.S., and F. CHAPMAN, Esq., A.L.S., F.R.M.S. (Communicated by permission of the Director-General of H.M. Geological Survey. Read March 25th, 1896.)

BARRY ISLAND lies off the northern coast of the Bristol Channel, about 7 miles south-west of Cardiff. Until the year 1884 it was separated from the mainland by the tidal estuary of the Cadoxton River on its northern side, and on the east by a tract covered at high water, but in which the solid rock cropped up through the tidal deposits at frequent intervals, the most conspicuous prominences being known as the Coston, Mark, Bendrick, and Black Rocks.


In the absence of evidence to the contrary we may assume that the course followed by the river at this time was its original course, for it falls into the general south-westerly direction of the rest of the valley. The numerous outcrops of rock, moreover, in the tidal area east of the island make it unlikely that there was an outlet here of sufficient depth to drain the marshes behind it. This tidal area seems to have been one of three low *cols* in the water-parting on the southern side of the Cadoxton Valley. One of these would separate the western part, or the Little Island, from the main part of Barry Island were it not for a ridge of blown sand; another occurs east of Hayes Farm, where, as shown by the Ordnance level 19 given on the map facing this page, the alluvial marsh of the Cadoxton River closely approaches the present coast. The third, presumably a trifle lower than either of the others, was submerged during the subsidence of the land, of which proof will be given in the following paper. It was therefore as a direct consequence of this subsidence that Barry was separated from Hayes Farm and became an island, while a slight increase in the extent of the movement would have given us three islands instead of one as the result of the submergence of the old water-parting.

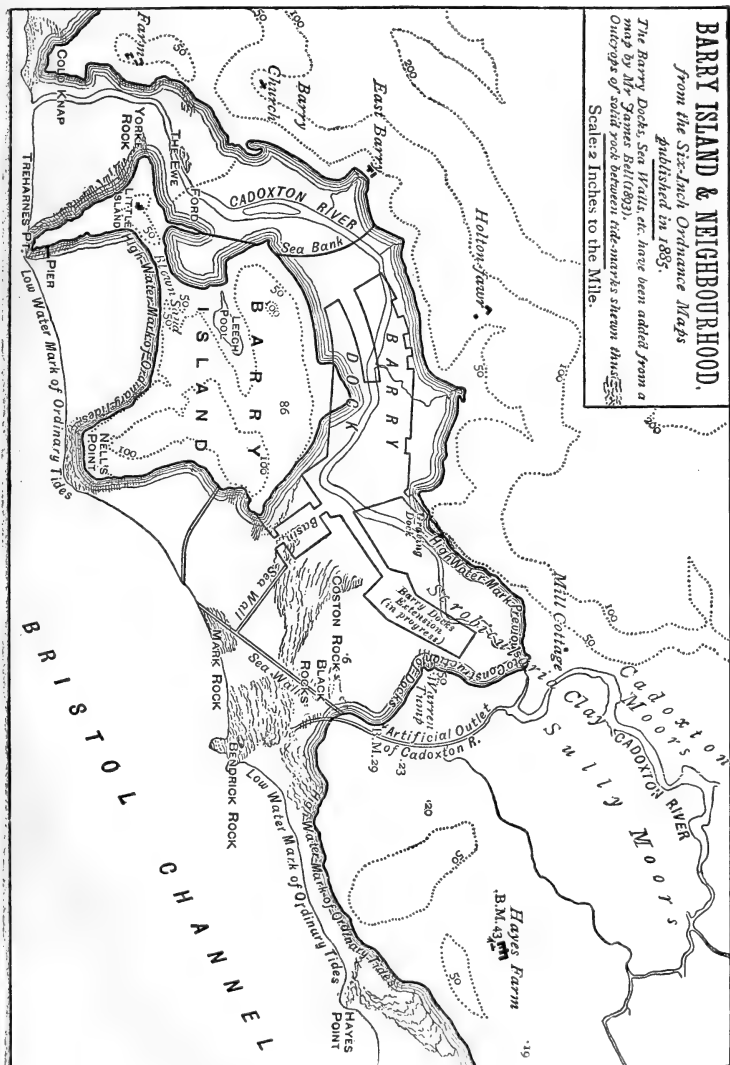
As to the date of the insulation of Barry, it will be seen subsequently that it had not taken place before Neolithic times; on the other hand the island is, I believe, referred to as such in the earliest historical records.

In 1884 the Barry Docks were commenced. The river was diverted from its ancient course and carried to the sea by an artificial cut east of the gap referred to. Its former valley on the northern side of the island was partly filled up and partly excavated to form a dock, the entrances to which were made in the tidal area east of the island, the sea being excluded by a wall. Subsequently a second dock (shown on the map as 'Barry Docks Extension') was commenced in this reclaimed area, and it was the excavation made

# BARRY ISLAND & NEIGHBOURHOOD.

from the Six-Inch Ordnance Maps  
published in 1885.

The Barry Docks, Sea Walls, etc. have been added from a  
map by Mr James Bell (1893).  
Outcrops of solid rock between tide-marks shown thus   
Scale: 2 Inches to the Mile.



for this purpose that I had the opportunity of examining in the course of my duties on the Geological Survey in 1895.

The history of the invasion of the river-valley by the sea through the gap mentioned clearly reveals itself in the sequence of deposits ; but, more than this, the river-alluvium presents a series of freshwater beds and land-surfaces, whose position in relation to the present sea-level proves that a great change in the level of the land took place during and after Neolithic times.

On some of my visits to the Dock I had the advantage of the assistance of Mr. F. T. Howard, F.G.S., and of Mr. J. Storrie, to the latter of whom I am indebted for much information respecting the sections exposed in the earlier dock, and also for the identification of some of the specimens from the present excavation. To my colleague Mr. Clement Reid, however, I am indebted for a thorough examination of the whole of my specimens, and for the identification of both plants and shells, together with critical remarks thereon. Prof. Rupert Jones, F.R.S., has kindly furnished me with the list of ostracoda, etc., given in the Appendix.

The natural topography of the tract is preserved on the 6-inch Ordnance maps, Glamorgan L. and LI. (published 1885, surveyed in 1878), from which the accompanying map (p. 475) has been prepared. The high-water mark of ordinary tides being shown on these maps in the usual manner, we are able to see that the whole of the new dock is being excavated in ground that was covered at high tide, though it pretty closely approaches the eastern shore at a point known as Warren Tump (now levelled). The extreme southern point of the dock lies near what was formerly a shoal known as Coston Rock. In both these parts the excavation is principally in the solid rock, but elsewhere it generally fails to reach the bottom of the alluvial deposits. These may be enumerated as follows :—

- |  |  |
|--|--|
| 1. Blown Sand.   | } Recent subaerial and tidal deposits. |
| 2. <i>Scrobicularia</i> -clay.   |  |
| 3. Sand and gravel.  |  |
| Strong line of erosion.  |  |
| 4. Blue silt, with many sedges.  |  |
| 5. The Upper Peat Bed ; about 4 feet below Ordnance-datum.   |  |
| 6. Blue silty clay, with many sedges.  |  |
| 7. The Second Peat, a thin layer only.   |  |
| 8. Blue silty clay, as no. 6.  |  |
| 9. The Third Peat, many large logs and stools, and roots in place underneath ; about 20 feet below Ordnance-datum. |  |
| 10. Blue silty clay, with reeds, willow-leaves, and freshwater shells.   |  |
| 11. The Fourth Peat, with large trees and roots in place. Land-shells numerous.                                    |  |
| 12. An old soil with roots and land-shells ; about 35 feet below Ordnance-datum.                                   |  |
| Rock in place.   |  |

By the kindness of Mr. James Bell, Engineer to the Barry Dock Company, I have been furnished with the following levels :—

	Above Ordnance- datum. feet.	Below Ordnance- datum. feet.
Quay-level, coping round Dock, Basin and Deep Lock ...	26.50	
High-water ordinary spring tides .....	19.70	
High-water ordinary neap tides .....	11.30	
Mean sea-level at Barry .....	1.60	
Low-water ordinary neap tides .....		8.3
Low-water ordinary spring tides .....		16.4
Bottom of Dock .....		20.0

1. The blown sand occurs only on the eastern side of the tidal area, whence it was evidently drifted by the south-west winds. The supply was never great, and is now of course entirely cut off.
2. The *Scrobicularia*-clay occurs in considerable force towards the north-eastern end of the excavation. It is a stiff, brownish clay, jointing vertically as it dries. It contains an abundance of *Scrobicularia plana*, with the valves united, and in this and other respects resembles the mud which is now being deposited in the more sheltered parts of the Bristol Channel. In the present case it found no rest on the shoals east of the island, but accumulated in some force from near Warren Tump upwards along the river-valley, as indicated on the map. The greatest thickness seen in the dock was 9 feet.
3. This sand and shingle forms the base of the *Scrobicularia*-clay, into which it passes insensibly upward. It ranges from 2 to 8 feet in thickness, according to local circumstances, and is full everywhere of recent shore-shells, all more or less rolled. Among these the following species have been identified by Mr. Clement Reid:—*Scrobicularia plana*, *Tellina balthica* (the thin-shelled estuarine form), *Cardium edule*, *Patella vulgata*, *Littorina littorea*, *L. rudis*, and *L. obtusata*.

Southward this sandy and gravelly tidal wash extends in a patchy manner among the rocky shoals towards the present foreshore, where it is still in course of formation. The deposits described above were all in process of being laid down, until the area was taken in hand by the Barry Dock Company in 1884. They rest upon a conspicuously eroded surface of the strata about to be described, with which also they contrast strongly in their contents and character. The erosion is attributable to the scour of the tide when the sea first gained access to the estuary round the eastern end of the island.

The series of deposits upon the description of which we now enter forms a continuous sequence from top to bottom. It may generally be described as a mass of fine clayey silt with abundant remains of sedges in the position of growth throughout, and with four or more bands of peat, only three of which, however, are of any importance. For convenience of reference I have numbered the beds all through, but the clays or silts which fall under the figures 4, 6, and 8 are practically identical. The greatest thickness seen amounted to about 35 feet.

North-eastern end of Warren Tump. N.E. Dock.

Near Warren end of Tump.

ORDNANCE DATUM

30 YARDS OMITTED

260 YARDS OMITTED

N.W. Near Entrance.

Southern angle of Dock.

S.W. S.E.

Not seen

Scale for Vertical and Horizontal distances.

0 10 20 30 40 50 60 70 80 90 100 ft. 50 yds. 100 yards

2 = *Serbicularia*-clay.  
3 = Sand and gravel.  
4, 6, 8, 10 = Blue silt with sedges, etc.  
5, 7, 9, 11 = Peat Beds.  
12 = Soil below Lowest Peat Bed.

Recent Marine Deposits.

Estuarine Deposits, etc.

4. Over the eastern and southern parts of the excavation, a thickness of blue silt ranging from 1 to 6 feet lies next below the recent tidal deposits, but on the north-western side, the tidal erosion having been somewhat greater, this uppermost silt has been washed away and the tidal deposits rest directly upon the peat-bed no. 5. The silt, like the others to be described, is crowded throughout with the roots and rotten stems of sedges in the position of growth, while at the bottom a few foraminifera (see Appendix, p. 485) give the deposit a slightly estuarine character.
5. This peat-bed forms one of the most conspicuous bands in the series. It ranges from 1 to 2 feet in thickness and persists over the whole of the excavation (and, as I was informed by Mr. Storrie, through the old dock also) except in those parts where the rock-surface rises in one of the shoals referred to. In such cases the peat-bed, slightly rising as it approaches the rock, thins away to a feather-edge, but comes in again at its proper level as the rock-surface falls. It keeps at a fairly constant level of about 4 feet below Ordnance-datum. Where fully developed it presents the following details:—
- 5 a. Laminated peat with logs (including, according to Mr. Storrie, willow, fir, and oak), passing down into
- 5 b. Light-coloured flexible marl, composed of the shells of ostracoda with much vegetable matter.
- 5 c. Shell-marl composed principally of the shells of *Limnæa*, *Bythinia*, etc., with many ostracoda and much vegetable matter.
- 5 d. Peat with logs of oak, etc. (one measuring 5 feet in length by

10 inches in diameter). A Neolithic worked flint was found by Mr. Storrie in this bed.

The ostracod- and shell-marls occurring in this peat are best developed in the southern angle of the excavation. As the peat-bed approaches the flanks of one of the rock-shoals previously referred to, it curves slightly upward, and in such cases the shell-marls thin out; at the same time logs of wood become more abundant. It may be supposed that these slightly inclined portions of the peat were formed at the margin of the water in which the shell-marls were accumulating, and that the logs were stranded in the positions which they now occupy.

The worked flint referred to was found by Mr. John Storrie after I had left the district. He picked it out from the peat (5*d*), three inches below the shell-marl, and within half a yard of it noted a stone containing glauconitic grains in the shell-marl (5*e*). The implement is made from a light grey chalk-flint, derived possibly from the drift-deposits of the district. Sir John Evans, to whom I showed the specimen, determined it to be a broken fragment of a polished celt, and Prof. Hughes further pointed out to me that it seems to have been used subsequently as a strike-a-light. The fragment is only about an inch long, but shows parts of the two ground faces of the celt, and of one of the ground edges; it can be matched exactly in shape (and, as it happens, in colour) by a polished celt from Mildenhall in Suffolk, which was given me for comparison by Prof. Hughes.

It may be mentioned here that two bone-needles, now in the Cardiff Museum, are said to have been found in this peat-bed during the construction of the first Barry Dock.

The only bone which I have seen or heard of was a fragment of an antler, probably of red deer, which had been thrown aside by the workmen. It clearly came from some part of the fresh-water series.

The ostracod-marl (5*b*) has been examined for me by Prof. Rupert Jones, F.R.S., who furnishes the full list of forms given in the Appendix. The brackish or freshwater *Cytheridea torosa*, Jones, forms the bulk of the deposit. The shell-marl (5*c*) is considered by Mr. Clement Reid to have been formed in a nearly freshwater tidal marsh. It consists mainly of *Limnæa* and decayed *Chara*. He determines also the following shells and plants:—

*Succinea elegans*.  
*Velletia lacustris*.  
*Limnæa auricularia*.  
 — *peregra*.  
*Planorbis albus*.  
 — *nautilus*.  
 — *nitidus*.  
*Valvata piscinalis*.  
 — *cristata*.

*Bythinia tentaculata*.  
*Entomostraca*.  
 —  
*Rumex crispus*.  
*Atriplex*.  
*Salix*.  
*Potamogeton*.  
*Naias marina*.  
*Chara*, two species.

Mr. Reid remarks that the occurrence of the pine (as identified by Mr. Storrie) and of *Naias marina*, both plants unknown in Wales during the historic period, suffices to distinguish this peat from any recent deposit.

6. This blue silty clay precisely resembles no. 4. It ranges from 5 to 7 feet in thickness.
7. The second peat is an impersistent brown band never exceeding 8 inches, and averaging about 3 inches in thickness. Its upper and lower limits are indefinite, and it suggests merely that for the time being plant-remains were accumulating more rapidly than mud. Mr. Reid describes it as 'a marsh-peat, apparently composed mainly of sedges (*Scirpus maritimus*).'
8. This resembles nos. 6 and 4, and is from 5 to 7 feet thick. In its upper part, immediately under the peat-bed no. 7, it contains shells, among which Mr. Reid identifies *Melampus myosotis*, *Helix arbustorum*, *Pupa*, and *Hydrobia ventosa*.  
Upright stems of a sedge, probably *Scirpus maritimus*, occur throughout this bed as through all the other silts.
9. This peat occurs at or close to the bottom of the dock—that is, at 20 feet below Ordnance-datum. It rarely exceeds 8 inches in thickness, but is persistent. In several places it is made up almost entirely of large timber, both trunks and stools of trees, while in one section roots and rootlets extending downward from the peat into a soil composed of disintegrated Keuper Marl were finely displayed. I give the section at this point in full:—

*Section about the middle of the North-western side of the Dock.*

	feet.	inches.
2. Brown clay with <i>Scrobicularia</i> .....	0 to 1	0
3. Sand and gravel with recent marine shells.....	5	0
Line of erosion.		
5. Peat.....	1	6
6. Blue silty clay .....	7	0
7. Peat .....		3 to 4
8. Blue silty clay .....	5	0
9. Peat with large logs, including some of oak .....		3 to 8
Decomposed green Keuper Marls, traversed by roots in position of growth and joining on to the peat above.		
Among the roots are some of conifers .....	3	0

Close by this spot the rock-surface rises on the flanks of one of the shoals referred to above; the beds thin out in succession against this slope (as shown in the section on p. 478), and it is for this reason that the sequence ends here with No. 9. The clear exposure left no doubt that the roots and rootlets were embedded in the position of growth in their native soil, nor was there any difficulty in tracing them upward into the mass of rotten wood that constituted the peat. In examining this section I had the advantage of the assistance of Mr. Storrie, to whom I am indebted for the identification of the woods.

Mr. Reid describes a specimen of this peat collected at a few yards distance as consisting of 'a tough mass of vegetable matter, principally sallow and reed, both roots and stems.



It also contains seeds of *Valeriana officinalis* and *Carex*, and elytra of beetles. There is no evidence of salt water.' I infer that the peat was formed in the one case as a true forest-bed along the margin of a swamp, and in the other by the growth of water-weeds within the limits of the morass.

- 10 and 11. These strata lay below the dock-bottom and were exposed only in the excavation for the foundations of walls, etc. Fortunately a good exposure of the important part of them was accessible about halfway between the entrance and the southern angle of the dock. The section commenced at the dock-bottom—that is, at the peat last described (no. 9); in the upper part it was timbered up, but at a depth of about 9 feet blue silty clay (no. 10) of the usual character could be seen and dug out through the timbers; at 12 feet below the dock-bottom the silt was succeeded by peat no. 11, and from here downward the section was open.

*Section below the Dock-bottom south of the Entrance.*

		feet.	inches.
10.	Not seen, but according to information all blue silty clay.	10	0
	Blue and greenish silt, full of reeds and containing leaves and land-shells; in the upper part foraminifera .....	2	0
11.	Peat with much timber .....	3	4
12.	Reddish clayey gravel with land-shells and penetrated by roots in place; passing down into red and green grits, limestone, and marls.		

With the exception of the foraminifera from the lower part of the silt (no. 10), there is nothing in this section to suggest the presence of salt or brackish water. The list of the microscopic organisms is contributed in the Appendix with the remark that the bed is quite marine, but the molluscs and plants enumerated below seem to modify this conclusion.

The red clayey gravel below was an unstratified deposit, including large angular fragments of the underlying rock. It was traversed by a network of roots ranging up to 3 inches in diameter, one of which at least was connected with one of the masses of wood in the peat above. Some of them also had moulded themselves against or between the angular blocks of rock, as would happen with roots growing in such a soil. Many had small twigs attached to them, while much of the deposit was more or less traversed by root-fibres. Some roots ran horizontally, but many vertically, and of the latter several were followed down for 3 feet below the base of the peat without reaching their terminations. The rock at this point is rising somewhat sharply, so much so that within 50 yards it touches the Upper Peat (no. 5), as shown in the section on p. 478. It might, therefore, have yielded some talus, but the gravel was totally unstratified and seemed rather to be rock decomposed in place. The evidence leaves no room for doubt that this peat is an old land-surface, lying at a depth of 35 feet below the present Ordnance-datum.

Mr. Clement Reid furnishes me with the following information respecting these deposits :—

10. This greenish sandy silt is full of reeds and contains leaves of willow, and land- and freshwater shells, such as *Limnæa auricularia*, *Planorbis albus*, *P. nautilus*, *Hydrobia ventrosa*, *Valvata piscinalis*, and *V. cristata*; *Salix capræa* and *Phragmites*.
11. This peat contains much broken oak-wood, mixed with seeds and shells, *Hyalinia* (*Zonites*), etc. A thin seam is full of willow-leaves and contains ostracoda, *Hyalinia*, and apparently *Pisidium* and *Planorbis*; the shells are much crushed.

Oak, *Quercus robur* (wood).  
 Hazel, *Corylus avellana* (twigs and nut).  
 Cornel, *Cornus sanguinea* (seeds).  
 Hawthorn, *Cratægus oxyacantha* (seeds).  
 Bur-reed, *Sparganium* (seeds).  
 Sallow, *Salix capræa* (leaves).

12. This old soil contains :—

Bird (femur of small species about the size of the stint).

*Charychium minimum*.  
*Helix arbustorum*.  
 — *rotundata*.  
 — *hispidula*.  
*Hyalinia*.  
*Succinea*.  
*Limnæa truncatula*.

*Pupa*.  
*Valvata piscinalis*.  
*Cardium edule*, two fragments  
 (? brought by gulls).  
*Cratægus oxyacantha* (seed).  
*Cornus sanguinea* (seed).  
*Quercus robur* (wood).

Mr. Reid concludes from his examination of the specimens that the lowest land-surface represents a true forest-growth, such as could only live at an elevation clear of the highest tides; one tide in the year would have sufficed to alter markedly the character of the fauna and flora in the deposit. Subsequently to the growth of this oak-forest a slow subsidence seems to have taken place, turning the land-surface into a shallow lake full of reeds and freshwater shells, the only indication of any salt being the occurrence of *Hydrobia ventrosa*, a shell which is seldom found in purely fresh water, and the foraminifera enumerated in the Appendix. The third peat (no. 9) Mr. Reid judges from the specimen submitted to him to indicate swampy ground rather than a true land-surface, but it will be remembered that in another section the existence of roots in place beneath the bed was clearly shown. The silt above (no. 8) he judges to be estuarine in its upper part, where it yielded foraminifera, *Melampus myosotis*, *Hydrobia ventrosa*, *Helix arbustorum*, and *Pupa*, while the peat (no. 7) he considers to be a compressed mass of sedges and not a land-surface. Of the highest peat (no. 5) Mr. Reid remarks that the contained fossils suggest at first a purely freshwater origin, but closer examination shows a noticeable absence of all species that are sensitive to the addition of a little salt, and one of the plants, *Naias marina*, is usually found within the reach of an occasional tide. The *Naias*, he points out, is of special interest, for at the present day it is known from Britain in one locality only, in Norfolk, though it occurs also in the Cromer

Forest Bed. Its recent distribution on the Continent is also very partial, but its seeds have lately been noted in abundance in peaty deposits, perhaps of the same age as those of Barry, in parts of Sweden and Holstein.

Mr. Reid remarks also that there is nothing in the fauna or flora to indicate any change of climate.

The facts detailed above seem to admit of but one explanation, namely, that the land has subsided at least 55 feet since the formation of peat no. 11. In dealing with such deposits we have to bear in mind that the sea is capable of raising barriers against itself, and that behind such barriers freshwater deposits may be forming, or even a land-surface may exist at a level below that of the highest tides, though never below mean sea-level. As bearing on this question I have noted from the Ordnance-map the levels of some of the marshes now bordering the Bristol Channel:—

	Feet above Ordnance-datum.
Sully Moors, the alluvial flat of the Cadoxton River, 1 mile above Barry .....	18
Cardiff (Grange Town), near the Taff River .....	18
Cardiff East Moors.....	20 to 22
near the Rhymney River .....	18
Cardiff (Cooper's Fields) .....	25
Peterstone Wentloog, 1 mile N.W. of .....	15
"                    1 mile N.E. of, and near a 'gout' .....	13

In all these cases, except perhaps the Cooper's Fields, the tide would occasionally overflow the land, were it not artificially kept out. Assuming for the sake of argument that a surface 20 feet above Ordnance-datum is the lowest that would now be safe from such periodic incursions of salt water, we have 55 feet as the difference in level between the land-surface, peat no. 11, and the lowest possible at the present day. At Porthkerry,  $1\frac{1}{2}$  mile west of Barry, a small stream with an alluvial flat about 150 yards broad debouches upon the shore. The sea has blocked the valley by a barrier of shingle, through which the fresh water escapes by percolation. The alluvial flat is liable to floods, though not, I believe, through the incursion of salt water, but only by the ponding back of the fresh. The level of this marsh is about 40 feet above Ordnance-datum, or 75 feet above the lowest peat (no. 11) of Barry Dock.

In none of these alluvial flats, nor elsewhere in the Bristol Channel, do we approach conditions under which the Barry Dock deposits could have been formed. If we assume that the sea had raised against itself an effectual barrier at the mouth of the Cadoxton River, and that it had not yet gained access to the river-valley by the gap on the eastern side of the island, we must then allow the existence of a freshwater lake, for the land-water would accumulate behind the barrier to at least mean sea-level. That is to say, we should have to assume that water stood at a depth of over 36 feet where we find evidence of a land-surface, with forest trees growing

in place and abundant land-shells. The same sort of evidence, in a scarcely less striking degree, is presented by every layer from the bottom to the very top of the series. There is, in fact, no part of it that could be formed with the land at its present level.

It will be noticed that the Cadoxton River flows for much of its course over Keuper Marls and the conglomerate or limestone which form the base of that series, but that at the coast it traverses the Carboniferous Limestone. In the softer rock its valley is broad and occupied by the alluvial flat, of which the Sully and Cadoxton Moors form part, but in the Carboniferous Limestone it narrows down to about 100 yards. It was in this broad area of obstructed drainage that the deposits described above accumulated, and no doubt the regularity with which they were laid down, and the gentleness with which estuarine influence was occasionally insinuated, was largely due to the narrowness of the outlet. At the time of the earliest land-surface, when the land stood not less than 55 feet higher than at present, the sea must have been still farther removed, but how much farther it is not possible to say. Though the Carboniferous Limestone would waste with extreme slowness, there may have been extensive post-Glacial deposits outside Barry Island, of which the Bristol Channel tides would make short work, so that it is doubtful how far the contours of the present sea-bottom are those of a submerged land-surface, or to what extent they have been modified by marine erosion. It is worth noticing that the only part of the Bristol Channel, south and east of Barry, which exceeds 60 feet in depth is a rather narrow trough about 2 miles south of the Welsh coast.

At any rate, we may suppose that the alluvial flat of the Sully and Cadoxton Moors occupies what was a generally freshwater estuary, occasionally dry enough to support a forest-growth on its margins, but as a rule swampy and densely overgrown with sedges, etc. By a more or less continuous sinking of the land the swamp tended to become a shallow lake, nearly but not wholly beyond the reach of the tide, until the subsidence admitted the sea by the gap east of Barry, thus separating that island from the mainland, and burying the estuarine series under true marine and tidal muds. The occurrence of the fragment of a polished flint-implement in the uppermost peat proves that the subsidence was in progress in Neolithic times, but had not yet sufficed to insulate Barry Island.

In conclusion, I should mention that there is a copious literature on both submerged forests and raised beaches in the Bristol Channel. The re-survey of the district, however, by the Geological Survey being in progress, I hope that much fresh information will be forthcoming, and I have confined myself to a description of the one section that I have had an opportunity of examining, more especially as that section seemed unusually complete in itself. In dealing with the subject generally, both the earlier upward movement implied by the raised beaches, and the later downward movement proved by the submerged land-surfaces, I shall hope to do full justice to my numerous predecessors.

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## APPENDIX.

REPORT on the MICROZOA in MARL and SILTS from BARRY DOCK,  
near CARDIFF.

[This has been drawn up by MR. FREDERICK CHAPMAN, A.L.S.,  
F.R.M.S., with the advice and co-operation of Prof. T. RUPERT JONES,  
F.R.S., F.G.S.]

## A. OSTRACODA.

(1) From the Clay above Upper Peat (No. 4 of p. 478).

1. CYTHERIDEA TOROSA (Jones), var. TERES, Brady and Robertson.  
See above, p. 479.

This has been previously recorded from Cardiff (New Dock Basin).  
Two specimens.

2. LOXOCONCHA ELLIPTICA, G. S. Brady.

*L. elliptica*, G. S. Brady, 1868, Trans. Linn. Soc. vol. xxvi. p. 435,  
pl. xxvii. figs. 38, 39, 45-48; pl. xl. fig. 3.

Previously recorded from Cardiff (New Dock Basin). Frequent.

(2) From the Upper Peat (No. 5 b of p. 478).

1. CANDONA PUBESCENS (Koch).

*Cypris pubescens*, Koch, 1837, 'Deutschlands Crustaceen,' etc.  
Heft xi. p. 5.

*Cypris setigera*, Jones, 1857, Monogr. Tert. Entom. (Pal. Soc.)  
p. 12, pl. i. fig. 6.

*Candona compressa*, Brady, 1868, Trans. Linn. Soc. vol. xxvi.  
p. 382, pl. xxvi. figs. 22-27.

*Candona pubescens*, Brady & Norman, 1889, Sci. Trans. R.  
Dublin Soc. ser. 2, vol. iv. p. 101, pl. xii. figs. 32-37 (limbs, etc.).

This species has been recorded from post-Tertiary deposits in  
Berkshire and Cambridgeshire; and it occurs as a recent fresh-  
water form in Great Britain and Europe.

Examples still bearing the short bristles on the exterior of the  
valves are found in the deposit from Barry Dock. Frequent.

2. CANDONA SUBÆQUALIS, Jones.

*C. subæqualis*, Jones, 1857, Monogr. Tert. Entom. (Pal. Soc.)  
p. 20, pl. i. figs. 9 a-c.

This is already known as a post-Tertiary freshwater form from  
Essex.

Two specimens; Barry Dock.

3. CANDONA CANDIDA (Müller).

*Cypris candida*, Müller, 1785, Entom., etc. p. 62, pl. vi. figs. 7-9.

*Candona candida*, Baird, 1845, Trans. Berwick. Nat. Club, vol. ii.  
p. 153; Jones, 1857, Monogr. Tert. Entom. (Pal. Soc.) p. 19, pl. i.  
figs. 8 a-f; Brady and Norman, Sci. Trans. R. Dublin Soc. ser. 2,  
vol. iv. 1889, p. 98, pl. x. figs. 1, 2, & 14-23 (including varieties).

A Pliocene, post-Tertiary, and recent freshwater species.  
Frequent, Barry Dock.

4. *CANDONA LACTEA*, Baird.

*Candona lactea*, Brady and Norman, 1889, Sci. Trans. R. Dublin Soc. ser. 2, vol. iv. p. 100.

A post-Tertiary and recent freshwater species; Great Britain and Europe.

Frequent; Barry Dock.

5. *DARWINULA STEVENSONI*, Brady and Robertson.

*Darwinella Stevensoni*, Brady and Robertson, 1874, Monogr. post-Tert. Entom. (Pal. Soc.) p. 141, pl. ii. figs. 13-17.

*Darwinula Stevensoni*, Brady and Norman, 1889, Sci. Trans. R. Dublin Soc. ser. 2, vol. iv. p. 122, pl. x. figs. 7-13.

A Pliocene, post-Tertiary, and recent freshwater species; Great Britain and Europe.

Common; Barry Dock.

6. *LIMNICY THERE INOPINATA* (Baird).

*Limnicythere inopinata*, Brady, 1868, Trans. Linn. Soc. vol. xxv. p. 419, pl. xxix. figs. 15-18, pl. xxxviii. fig. 9, pl. xxxix. fig. 1.

This strikingly sculptured species is a post-Tertiary and recent form; inhabiting fresh and estuarine waters, and found sometimes in seawater near the coast.

Very common; Barry Dock.

7. *CY THERIDEA TOROSA* (Jones), *var. TERES*, Brady and Robertson.

*C. torosa*, *var. teres*, Brady and Robertson, Ann. Mag. Nat. Hist. 1870, ser. 4, vol. vii. pp. 21, 22; Brady, Crosskey, and Robertson, 1874, Monogr. Post-tert. Entom. p. 178, pl. vii. figs. 1, 2.

This variety is distinguished from the type by the absence of the knobs so conspicuous in *C. torosa*. The specimens here under notice vary very much in size, measuring  $\frac{1}{60}$  to  $\frac{1}{8}$  inch (0.42 mm. to 1.38 mm.) in length. The external surfaces of the valves are marked with minute pittings, disposed in a somewhat concentrically lineate manner. The usual transverse median sulcus is well-marked in nearly all the specimens, but it is better developed in the larger individuals. There is a short stout spine on the margin of the right valve at the posterior ventral angle. The valves of the male are narrower and more elongate than those of the female.

Previously known as a Pliocene, post-Tertiary, and recent freshwater and estuarine form; Great Britain and Europe.

Very abundant; Barry Dock.

(3) From the Clay above the Lowest Peat (No. 10 of p. 481).

1. *CY THER PELLUCIDA*, Baird.

*C. pellucida*, Brady and Norman, 1889, Sci. Trans. R. Dublin Soc. ser. 2, vol. iv. p. 126, pl. xiv. figs. 13-15.

This is an essentially brackish-water species, and has been before recorded from Cardiff (New Dock Basin) amongst other places. Common.

## 2. CYTHERURA PRODUCTA, G. S. Brady.

*C. producta*, G. S. Brady, 1868, Trans. Linn. Soc. vol. xxvi. p. 443, pl. xxxii. figs. 60, 61.

This species has been previously found at Cardiff (New Dock Basin). One specimen.

## B. FORAMINIFERA.

	From Clay (No. 4) above Upper Peat.	From Upper Peat (No. 5 b).	From Clay (No. 10) above Lowest Peat.
<i>Miliolina oblonga</i> (Montagu) ...	...	...	2
— <i>subrotunda</i> (Montagu) .....	...	...	1
<i>Cornuspira involvens</i> , Reuss .....	...	...	3
<i>Trochammina inflata</i> (Montagu) .	Frequent.	...	1
— —, var. <i>macrescens</i> , B. H.	1	...	3
Brady.			
<i>Textularia trochus</i> , d'Orbigny ...	...	...	1 small specimen.
<i>Bolivina textularioides</i> , Reuss ...	...	...	Common.
<i>Lagena globosa</i> (Montagu) .....	...	1	1
— <i>lævis</i> (Montagu) .....	...	1	...
<i>Polymorphina lactea</i> (W. & J.) ...	...	...	1 small specimen.
<i>Discorbina rosacea</i> (d'Orb.) .....	...	1	2
— <i>Bertheloti</i> (d'Orb.) .....	...	...	1
— <i>obtusa</i> (d'Orb.) .....	...	1	1
<i>Truncatulina Ungeriana</i> (d'Orb.)	...	...	1
<i>Rotalia Beccarii</i> (Linné). Dwarfed specimens.	Common.	2	Frequent.
<i>Nonionina depressula</i> (W. & J.)...	Common.	...	Very common.
<i>Polystomella striatopunctata</i> (F. & M.).	Very common.	1	Very common.
<i>Dendrophora erecta</i> (Str. Wright)	...	Frequent.	...

## 1. ? DENDROPHYRA ERECTA, Strethill Wright.

*Dendrophyra erecta*, Str. Wright, 1861, Ann. & Mag. Nat. Hist. ser. 3, vol. viii. p. 122, pl. iv. figs. 4 & 5.

Fragments of tubes, composed of loose sandy material, and usually tapering at one end, after the manner of the above form. There can be hardly any doubt that these post-Tertiary specimens are referable to the above species.

Frequent; Barry Dock.

## 2. LAGENA LÆVIS (Montagu).

*Lagena lævis*, Williamson, 1848, Ann. & Mag. Nat. Hist. ser. 2, vol. i. p. 12, pl. i. figs. 1 & 2.

A very minute, but perfect, example of this species; from Barry Dock.

3. *LAGENA GLOBOSA* (Montagu).

*Entosolenia globosa*, Parker and Jones, 1857, Ann. & Mag. Nat. Hist. ser. 2, vol. xix. p. 278, pl. xi. figs. 25-29.

*Lagena globosa*, Reuss, 1868, Sitzungsber. k. Akad. Wiss. Wien, vol. xlv. p. 318, pl. i. figs. 1-3.

A very small individual; from Barry Dock.

4. *DISCORBINA ROSACEA* (d'Orb.).

*Discorbina rosacea*, Parker, Jones and Brady, 1865, Ann. & Mag. Nat. Hist. ser. 3, vol. xvi. p. 25, pl. ii. fig. 71.

One specimen, of fair size; Barry Dock.

5. *DISCORBINA OBTUSA* (d'Orb.).

*Discorbina obtusa*, Brady, 1884, Rep. Chall. Foram. p. 644, pl. xci. fig. 9.

A young example of this form, with but few chambers.

One specimen; Barry Dock.

6. *ROTALIA BECCARII* (Linné).

*Rotalia Beccarii*, Brady, 1884, Rep. Chall. Foram. p. 704, pl. cvii. figs. 2 & 3.

Young specimens, but typical.

Two examples; Barry Dock.

7. *POLYSTOMELLA STRIATOPUNCTATA* (Fichtel and Moll).

*Polystomella striatopunctata*, Brady, Rep. Chall. Foram. p. 733, pl. cix. figs. 22, 23.

One specimen, of rather small size; Barry Dock.

## C. PLANTÆ.

From the Upper Peat (No. 5 b of p. 478).

Nucules and stem-fragments of *Chara*, sp.; *Campylodiscus* (Diatomaceæ).

From the Clay above the Lowest Peat (No. 10 of p. 481).

*Campylodiscus*. Frequent.

The lowest portion is quite marine; the higher upward one goes the more estuarine the material becomes.

## DISCUSSION.

Prof. T. RUPERT JONES referred to the importance of foraminifera as giving evidence of the presence of sea-water; and stated that some of the entomostraca from the ostracod-marl had a brackish-water habitat. He mentioned that the examination of the specimens was made by Mr. Chapman, and that he had only given help and advice.

The PRESIDENT said that the paper was of much interest to him,



as he had during many years past paid considerable attention to the submerged forests and peat-beds which have been found along the Welsh coast of the Bristol and St. George's Channels. Some submerged forests were noticed by the historian Giraldus Cambrensis in the 12th century, at spots now constantly covered by the sea; and there is other evidence to show that great encroachments have taken place in comparatively recent times. When the forests which contained oak, alder, birch, etc. as their chief trees, grew on the plains and in the valleys exposed to the westerly winds, it is clear that the sea must have been at a considerable distance; and it seems more than probable that the Bristol Channel was then mainly a tract of marshy plains traversed by important rivers. The trees in the forest at Whitesand Bay, Pembrokeshire, which he examined many years ago, had been deeply rooted in the underlying Boulder Clay, and many antlers of the red deer, a jaw of the brown bear, and a well-worked flint-flake were found by him in the peat-bed. Possibly the oldest of the beds referred to by the Author might belong to the same period, but the others appear to be of more recent date.

Mr. CODRINGTON said that the old beds of the river and 'pills' along the coast indicated subsidence at least as great as 55 feet. The rock-bed of the Wye at Chepstow was 42 feet below low water, having 40 to 50 feet of mud over it containing nuts, leaves, and oak-timber. In Milford Haven the rock-bottom of Myland Pill was 45 feet below low water, and that of the channel of the pill at Milford Docks deeper still, with 40 to 50 or 60 feet of mud. There were many such sections.

The AUTHOR replied to Prof. Jones that he had acknowledged the occasional invasion of the estuary by salt or brackish water, implied by the presence of foraminifera and some of the ostracoda. At the same time the entire absence from the estuarine beds of the marine shells which abounded in the overlying deposits was significant. The hypothesis of the President, that when the lowest peat was being formed the Bristol Channel was dry land traversed by a winding river had occurred to him also, and it was with this in mind that he had pointed out the existence of a deep narrow channel about 2 miles south of Barry. The relative levels of the peat-beds and the sea could not be explained by mere encroachment of the latter. No glacial deposits occurred either in the excavations or in the immediate neighbourhood. The existence of the numerous buried valleys referred to by Mr. Codrington, and the general character of the deposits filling them, were well known to him. They had been explored, however, chiefly by borings, and he attached greater value to observations made on such deposits *in situ*, and to specimens collected with every precaution against the mixing of the fauna and flora of different beds, than to the mangled débris brought up by the boring-tool.

28. *THE EOCENE DEPOSITS OF DORSET.* By CLEMENT REID, Esq., F.L.S., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey. Read April 29th, 1896.)

THE new survey of the western end of the Hampshire Basin having necessitated certain modifications in the geological map, it may be useful to lay the principal results before the Society. If the alterations were mere matters of detail, this would scarcely be worth while; but the more accurate mapping has led to the discovery of a sudden westerly change in the character of the Lower Bagshot Sands, and of a well-marked overlap at their base. The mapping of the Tertiary strata proves also that there is evidence of other periods of earth-movement in southern England, besides those already known,<sup>1</sup> and that we are dealing with one of those regions where folding affects the same area again and again.

When the Eocene strata are followed westward through Sussex and Hampshire into Dorset, one finds constant local changes in the lithological character of the deposits, though these changes seem all to tend in the same direction. Marine beds become less conspicuous, coarser, more estuarine, and estuarine deposits become truly fluvatile. Thus the London Clay, which exceeds 300 feet in thickness to the east, dwindles to less than 100 feet in Dorset, and becomes more sandy and pebbly, though still apparently of marine origin. The Woolwich and Reading Series—fluvio-marine at Newhaven and Portslade, and slightly so at Lancing—becomes more fluvatile westward, lenticular patches of subangular gravel appearing in it west of Wareham. To what extent the Reading Series rests unconformably upon the Chalk is difficult to say, though overlap is clearly recognizable in various places. The Lower Bagshot Sands also become coarser and more purely fluvatile westward, the change being a singularly rapid one in the neighbourhood of Dorchester. It is to this change in the Bagshot Sands, and the conclusions to which it leads, that attention will more especially be drawn in the following notes.

### 1. Woolwich and Reading Series.

The extreme variability of these deposits makes it difficult, till a large area has been examined, to master any general tendency in the variations. No particular bed seems ever to be traceable more than a short distance, the whole series being made up of a succession of alternating masses of red-mottled clay, loam, sand, and gravel. Plant-beds and marine strata alternate at Newhaven. At Brighton and Portslade the deposits are still of the Woolwich or fluvio-marine

<sup>1</sup> See Reid, 'Pliocene Deposits of North-western Europe,' *Nature*, vol. xxxiv. (1886) p. 341; Reid & Strahan, *Mem. Geol. Surv.* 'Geology of the Isle of Wight,' 2nd ed. 1889, chap. xiv.; Reid, 'Pliocene Deposits of Britain' *Mem. Geol. Surv.* 1890, pp. 69, 70; Strahan, 'On Overthrusts of Tertiary Date in Dorset,' *Quart. Journ. Geol. Soc.* vol. li. (1895) p. 549.

type. At Lancing the strata are mainly of the Reading type, consisting of alternations of red-mottled clay, loam, lignite, and sand; but even there certain ironstone-nodules near the base yield casts of marine shells. From Worthing westward the southern margin of the Hampshire Basin yields no evidence of marine conditions.

An increasing rarity of marine fossils is not the only change that takes place when the Woolwich and Reading Series is traced westward, for directly we pass from Hampshire into Dorset it is noticeable that the sands are often coarse and full of small splinters of flint. A few miles farther west, at Morden and at East Lulworth, lenticular masses of coarse subangular gravel make their appearance in the Reading Beds, and these gravels, especially at Morden, contain a considerable percentage of Greensand chert with sponge-spicules. This admixture of coarse sand and subangular gravel becomes still more marked towards the western limits of the formation, and the proportion of Greensand chert increases.

## 2. London Clay.

Though the London Clay thins and becomes more sandy to the west, there is no sign of shore or estuarine conditions, and even at its western limit it is apparently of purely marine origin. The flint-pebbles at the base of the formation are all perfectly rounded, as in other localities, and do not yield any evidence of beaches. The only fossil that I have seen from the London Clay in Dorset is an indeterminable bivalve, apparently a *Cyprina* or *Cytherea*, obtained from the basement-bed in a boring at Wimborne. This absence of fossils is, however, in all probability due to the sandy pervious nature of the deposit; for though more typical London Clay with septarian ironstone-nodules occurs, sections in unweathered material are very scarce. Throughout the Hampshire Basin the London Clay seems always to rest, with a sharp, slightly eroded junction, on the Reading Series; yet there is no trace of either unconformity or overlap, the thickness of the Reading Beds remaining approximately the same throughout.

## 3. Lower Bagshot Beds.

The changes undergone by the Bagshot Sands are even more marked than those that take place in the Lower Eocene strata. If we follow the southern margin of the Hampshire Basin we discover that the Sands are thin and scarcely recognizable in the Selsey Peninsula. In the Isle of Wight, however, they expand enormously, reaching 150 feet at the eastern end of the island and 600 feet at the western, where they contain lenticular masses of white pipe-clay with plant-remains. The Bournemouth cliffs show a tendency to the increase of coarse sands, containing small fragments of black grit, lydite (or radiolarian chert), and occasionally of Greensand chert; splinters of flint also begin to appear. Coarse sands of this character continue to be associated with the pipe-clays westward to beyond Wareham. Then sets in a change like that

undergone by the Reading Beds, but far more marked. The Bagshot Sands become coarser and gravelly, unworn flints and flint-splinters become abundant, and mixed with these is found a quantity of subangular Greensand chert, like that occurring in the Reading Beds. There is, however, one character which enables us easily to distinguish between the Bagshot and Reading gravels. The Reading gravels consist of flint and chert, with an occasional quartz-pebble: careful search yielding nothing else except one or two small quartzite and grit-pebbles. Bagshot gravels, on the other hand, contain, besides flint and chert, so much quartz and hard subangular Palæozoic rocks as to make the finer screened material look like a Cornish beach. They yield also a certain quantity of Purbeck marble and other Purbeck rocks, though I have been unable to discover any trace of Portland Beds or of the Oolites below.<sup>1</sup>

This gravelly condition of the Bagshot Series first becomes conspicuous in the large pits close to Moreton railway-station, where 40 feet or so of the sands can be seen associated with seams of white pipe-clay. In this pit one can find fragments of all the rocks which occur in the coarser gravels farther west. It is noticeable also that the chert-fragments found in the lower part of the pit are often quite soft, so that they were at first mistaken for pebbles of pipe-clay, though they soon harden on exposure to the air. A softening of the chert-pebbles will explain the curious way in which the fragments are sometimes dented by each other and pitted by sand-grains, at a locality where neither earth-movement nor pressure has ever been extreme. As I found rounded quartz-grains half embedded in some of the flints it is possible that Chalk-flints also can to some extent be softened in a similar way.

To the west of Moreton the Bagshot gravels rapidly become much coarser, and as they change the Bagshot Series cuts through the London Clay and through the Reading Beds, till it rests immediately on the Chalk. The various outliers south and south-west of Dorchester all belong to the Bagshot Series, not to the Reading Beds as formerly supposed.

A study of the composition of the Eocene gravels shows distinctly that the rivers that brought them must have flowed from the west or south-west. Both Reading and Bagshot gravels become coarser and the stones more angular in that direction, and seem to occupy a valley eroded in the Secondary strata. But of the extent of this erosion it is difficult to obtain direct evidence, for the wide trough south-west of Dorchester, in which several of the Eocene outliers lie, is mainly a continuation of the syncline of the Hampshire Basin, not an eroded hollow. A considerable amount of erosion of the Chalk seems to have taken place before the Ridgeway and Blackdown (Hardy's Monument) outliers were deposited; but I am quite

<sup>1</sup> Some of these rocks are recorded by Sir Joseph Prestwich as occurring at Blackdown in gravel, which 'may belong to some part of the Glacial period,' overlying the Eocene beds. The gravels seem to me to be of Eocene age. See Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 41.

unable yet to say to what extent the position of these outliers is due to erosion as distinguished from folding. The Rev. O. Fisher states<sup>1</sup> that when the large ballast-pit on Bincombe Down was open during the making of the Ridgeway cutting, the Tertiary strata were seen to be vertical. Sir Joseph Prestwich<sup>2</sup> and Mr. Strahan,<sup>3</sup> however, in their sections, draw the Eocene base as markedly unconformable on the upturned Chalk. All that can now be clearly made out is that in certain parts of the old ballast-pit the Eocene strata are highly inclined. It is, however, so extremely difficult to obtain accurate dips in these deposits, owing to the occurrence of piping on a scale which I have never seen equalled, that it is unsafe in the present state of the section to express any confident opinion as to the exact relation of the Bagshot strata to the Ridgeway disturbance.

Though it may be impossible readily to prove by stratigraphical evidence the overlap of the Lower Bagshot Beds, yet the composition of the gravels demonstrates unmistakably this discordance. One finds on analysis that the gravels contain in the first place abundance of Chalk-flints. Next in abundance come numerous fragments of the Greensand chert already mentioned. The pieces are usually subangular, and of all sizes up to a foot in diameter; so they are not likely to have travelled far. The chert is probably derived from the Upper Greensand.<sup>4</sup> Numerous pebbles of vein-quartz, mostly under an inch in diameter, next attract one's attention, and it is not improbable that these may come from conglomeratic seams in the Wealden strata of the immediate neighbourhood. Fragments of Purbeck marble, sometimes silicified, are fairly common, and are associated with cherts and grits probably also of Purbeck age. All the rest of the material consists of subangular veined grits, hard sandstones, quartzites, quartz, radiolarian chert, and red and green jaspers; in fact, of hard siliceous material such as might be derived from the weathering of the Permian breccias of Devon. Black grit with small quartz-veins is abundant, and, like the radiolarian chert, suggests the Culm Measures as its source, though probably it also is derived secondarily through the Permian breccias. Budleigh Salterton Triassic pebbles are, however, entirely missing.

This peculiar composition of the gravels ought to give us a clue to the amount of denudation that had then taken place, and also to the direction in which the river flowed. The gravels of the Reading Series, containing Chalk-flints and Greensand chert, suggest that erosion at that period had only reached down to the Upper Greensand; though even this amount of erosion points to a distinct post-Cretaceous upheaval in the neighbourhood, which tilted the Chalk and brought Greensand within reach of the eroding agent, before the deposition of the Reading Beds.

During, or before, the Bagshot period there seems to have occurred another era of local disturbance, during which both

<sup>1</sup> *In lit.* [since published in Geol. Mag. for June 1896].

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xxxi. (1875) pl. i. fig. 2.

<sup>3</sup> *Ibid.* vol. li. (1895) pl. xviii.

<sup>4</sup> [Chert of identical character has since been found in the Upper Greensand near Abbotsbury.—July, 1896.]

Reading Beds and London Clay near Dorchester were so tilted as to lead to a sharp transgression of the overlying Bagshot gravels. It happens thus that within a distance of 3 miles the Bagshot gravels cut through both those formations. A short distance farther west, at Bincombe Down, the gravel has cut well into the Chalk, and there is little doubt that within a few miles it must have overlapped all the Cretaceous rocks and cut into Purbeck Beds. The reason why it is suggested that the Purbeck stones can only have come a short distance will be seen on looking at a geological map. Purbeck rocks might be obtained in the immediate neighbourhood of the Bagshot gravels, on the south side of the Bincombe fault; but they could not have been derived from regions farther west, as in that direction the Purbeck Beds had already been denuded and overlapped by the Greensand. This overlap becomes more pronounced westward, the Greensand resting unconformably on all the Secondary rocks, till at Haldon there is nothing between the Greensand and the Permian breccias. It thus comes about that no Jurassic fragments are found in the Bagshot gravels, with the exception of Purbeck rocks, which seem to have bordered the southern edge of the Eocene valley. The rest of the gravel was apparently derived from the higher part of the river-basin, where Greensand rests directly on Permian strata, even the Budleigh Salterton pebble-bed being overlapped and hidden.

It is noteworthy that the new evidence discovered in the western end of the Hampshire Basin strongly supports the idea that the pipe-clays of the Bagshot Series are derived from the weathering of the Dartmoor Granite, and that the Bovey Tracey outlier, so like the deposits around Bournemouth, is, as maintained by Mr. Starkie Gardner, of the same age and deposited in the same basin, though in Devon Eocene rest directly on Palæozoic rocks. Bovey Tracey is only a short distance from Haldon, and Permian breccias, Culm Measures, and granite rise into hills in the immediate neighbourhood. That district might have provided the whole of the material in the Bagshot gravels, with the exception of the Purbeck marble.

A consideration of the evidence now brought forward shows that besides the already-recognized earth-movements of intra-Cretaceous, early Eocene, Miocene, and Pliocene dates, there must have been folding during at least one other period in the same or closely adjoining areas. The earliest, or intra-Cretaceous, folding accounts for the marked unconformity of the Upper Cretaceous on all the older rocks. The second disturbance, either late Cretaceous or early Eocene, during which the Bincombe overthrust must have commenced, caused Reading Beds to overlap the Chalk and rest on Upper Greensand. A third disturbance allowed Bagshot Beds to cut across the upturned edges of the London Clay, Reading Beds, Chalk, and Greensand and reach the Purbeck and older rocks. Finally we have the well-known Miocene folding, which threw the whole of the Tertiaries of the Hampshire Basin into a series of sharp undulations with an east-and-west axis, and this movement

seems to have continued till early Pliocene times. It would thus appear that the district between Dorchester and Weymouth is one of those areas of weakness which are affected again and again by similar disturbances.

The discovery of the peculiar composition of the Eocene gravels of Dorset has thrown an unexpected light on the source of the material in the Pleistocene series. These gravels, from Brighton westward into Dorset, always contain a considerable proportion of Greensand chert of marked character, besides other foreign stones. Of these stones a considerable number have been shown to be glacial erratics brought by floating ice, though the glacial erratics are entirely confined to low levels and to the area between Brighton and Southampton Water.<sup>1</sup> Above that level and beyond that district the Plateau-gravels contain, however, large quantities of chert and also of Palæozoic grits and quartz. The cherts have usually been considered to point to derivation from a central Wealden axis. But when it is found that the masses become larger and more abundant westward, and that they are always associated with Palæozoic grits that could not be derived from the Wealden area, it is evident that they can have no connexion with the Weald, but clearly must have been derived from Devon and Dorset. Every kind of rock found in the Plateau-gravels of Sussex, Hampshire, and Dorset above the level of the glacial action has now been traced to the Bagshot gravels of Dorset, and through them to districts still farther west.

#### DISCUSSION.

Mr. STRAHAN said that he had had occasion to trace part of the Tertiary base-line while mapping the Secondary rocks in South Dorset, and that he had speculated on the age of the gravel-outliers near Dorchester. No clue, however, was forthcoming until the Tertiary deposits were mapped by Mr. Reid from Hampshire continuously westwards, and the overlap of the Bagshot Beds traced step by step. It had seemed to him that there was a marked discordance in the extreme west between the Eocene and Cretaceous; in fact, the Chalk seemed to have been carved into hill and dale before it was overspread by the Eocene. Moreover, in drawing a section through Bincombe, he had found that there was not room for the whole of the Chalk below the Tertiary outlier, and had been obliged to show a marked overlap by the latter, as had been previously done by Sir Joseph Prestwich. The Author's observations tended to confirm this conclusion. He considered that the Author had made a material advance towards solving an important problem in Tertiary geology.

Mr. MONCKTON remarked that if pebbles from the Permian of the West of England were found in the gravels described by the Author, it was rather surprising that the liver-coloured quartzites of the Triassic pebble-beds should not also occur. He asked whether there

<sup>1</sup> See Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 344.

was evidence founded on superposition of strata in well-sections or otherwise to show that the gravels are really of Reading or Bagshot age.

Mr. H. B. WOODWARD considered that the Author had proved his contention with regard to the composition of the Bagshot gravels. He had seen the gravel on Blackdown (Portisham), and, having found blocks of greywether in it, he had taken it for Drift. He was now prepared to believe anything; but he would ask the Author to state how he distinguished between the outliers of Bagshot gravel and those of Drift gravel, as the question of the overlap of the Bagshot Beds depended greatly thereon.

Mr. R. S. HERRIES said that there were several points of interest in this paper, such as the continued thinning of the London Clay towards the west, and the remarkable persistence in the thickness of the Reading Beds in spite of their changed character. The evidence of the Reading or Bagshot age of the gravels did not seem quite conclusive, and it might turn out that they were later still. The conclusion that the materials of which they and the later gravels are composed were derived from the west was most interesting, and there seemed every reason to suppose that it was correct.

Dr. G. J. HINDE also spoke, and the AUTHOR replied.



29. DISCOVERY OF MAMMALIAN REMAINS *in the Old River-gravels of the Derwent near Derby.* (Read April 29th, 1896.)

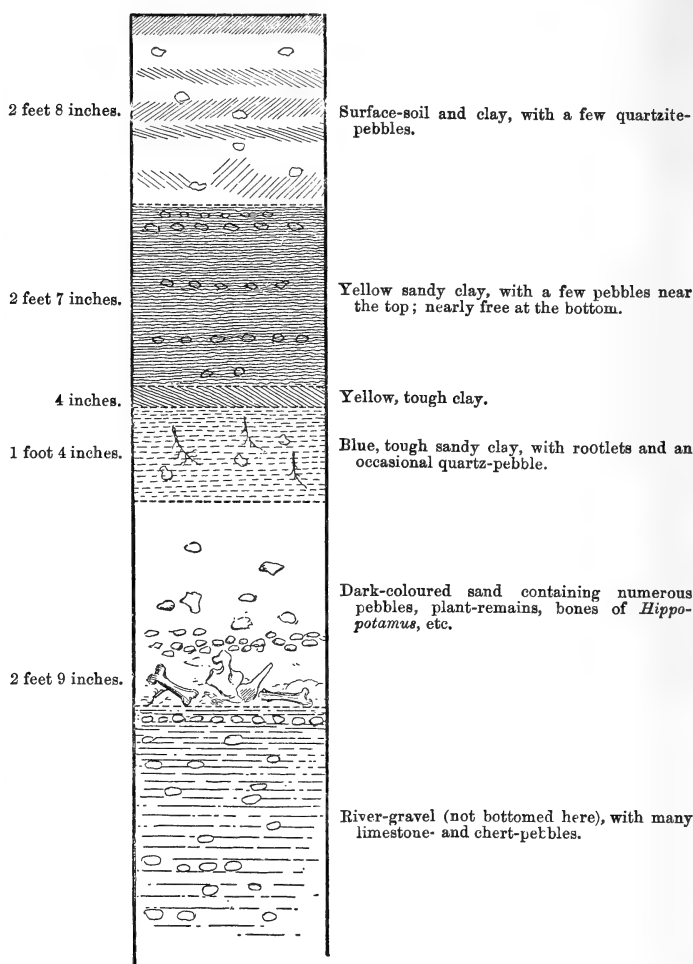
PART I.—By H. H. ARNOLD-BEMROSE, Esq., M.A., F.G.S.

THESE remains were discovered under the yard of the Crown Inn at Allenton, not quite 3 miles south of Derby. In March, 1895, Messrs. Offiler & Co. were sinking a well there for drinking-water. When it was partly bricked in, a strong unpleasant smell was noticed, several large bones were discovered, and the well was, in consequence, abandoned. The water rose very rapidly, and only twenty-one bones or fragments were taken out. These included the left femur of an artiodactyle, several vertebræ or portions of vertebræ, and fragments of ribs. The writers obtained them from Messrs. Offiler & Co., and after examination decided to excavate for the remainder. The funds necessary to defray the expenses were readily obtained from a few local gentlemen, on condition that the bones should be finally placed in the Borough Museum. The work was commenced on April 8th and entrusted to Mr. Durant, builder. During the day a hole, 8 × 6 feet, was dug through the clay, and the water rose in it to within 6 feet of the surface. On the second day the hole was deepened through the clay and sand to the top of the gravel (9 feet 8 inches below the surface). One complete bone and twelve small pieces, probably from the head, were obtained.

On the third day the clay was tunnelled on the eastern and northern sides, the total area excavated at the bottom being about 11 by 9 feet. The tunnelling was rendered necessary because of the small space available in that part of the yard, which was limited by buildings on three sides and a wall on the fourth. The main difficulty was to contend with the water which rose from the gravel and caused the sides of the pit to fall in, notwithstanding the timbering. Two large pumps were kept at work by relays of men during the whole of the second and third days, but in spite of this most of the work had to be done in water. Under these circumstances it was impossible to get up the bones without breaking some of them. One hundred and twenty-seven bones or fragments were found. They were numbered in the order obtained, and their relative positions were noted as accurately as possible. One or both of the writers was present during the whole time, and every bucketful of sand or gravel was carefully examined. The sand and gravel taken from near the head were washed in a sieve, but no loose teeth were found. Most of the bones were obtained during the latter half of the third day. No further discoveries being made, and the water gaining rapidly upon the pumps, further work had to be abandoned.

Samples of the clay and sand were taken from the pit, and measurements and notes of the deposits passed through were made by both writers together.

Fig. 1.



The above section shows the nature of the deposits passed through. The gravel is similar in character to that covering a large area to the north-east, and is apparently continuous with it.

The excavations were made to a depth of 9 feet 8 inches, and the beds of clay, sand, and pebbles were unbroken over the area excavated. No clear line of demarcation separated adjoining deposits, but the tough sandy clay passed into yellow clay above and dark sand below. The bones were all found in the dark sand resting immediately upon the lower gravel. A sample of the dark sand was dried and the constituents separated in a sieve with meshes

$\frac{1}{40}$  inch in diameter. The portion retained in the sieve (with the exception of some quartzite-pebbles, fragments of flint, and a few very much decomposed pieces of limestone similar to those found in the same gravel-terrace at Alvaston) was sent to Mr. Clement Reid, F.G.S., who kindly examined it for plant-remains. Mr. Reid reports that 'the plants indicate a moist meadow or swampy ground, and a temperate climate. I can say nothing more definite, as the species are all widely distributed. An elytron and thorax of a beetle were found in addition to the following plants :—

Plants found with *Hippopotamus*.

<i>Ranunculus aquatilis</i> , Linn.	<i>Valeriana officinalis</i> , Linn.
„ <i>sceleratus</i> , Linn.	<i>Eupatorium cannabinum</i> , Linn.
„ <i>Flammula</i> , Linn.	<i>Leontodon autumnalis</i> , Linn.
„ <i>repens</i> , Linn.	<i>Taraxacum officinale</i> , Web.
„ <i>bulbosus</i> ?, Linn.	<i>Ajuga reptans</i> , Linn.
„ <i>Sardous</i> , Crantz.	<i>Atriplex</i> ?
<i>Viola palustris</i> , Linn.	<i>Eleocharis palustris</i> , Linn.
<i>Montia fontana</i> , Linn.	<i>Scirpus pauciflorus</i> , Lightf.
<i>Rubus Idæus</i> , Linn.	<i>Carex</i> ?
<i>Potentilla</i> ?	<i>Isoetes lacustris</i> , Linn.'
<i>Hydrocotyle vulgaris</i> , Linn.	

Part of the sand which had passed through the first sieve was then sifted through others with meshes of  $\frac{1}{80}$  inch and  $\frac{1}{120}$  inch, and the various portions were examined under the microscope. It consisted for the greater part of a quartz-sand, the larger grains of which were well rounded, and the smaller subangular and broken, together with flakes of white mica, some of which showed a negative bisectrix in convergent light. In addition to these a very small proportion of a fine dark-coloured material and fragments ( $\frac{1}{40}$  inch to  $\frac{1}{80}$  inch in diameter) of probably plant or bone occurred, or perhaps both of these substances.

A sample of the blue sandy clay was similarly examined. It contained a few rootlets, and consisted of broken quartz-grains and a fine amorphous substance.

A sample of gravelly sand from the same gravel-terrace at Alvaston was also examined. Mr. Reid was unable to find any plant-remains in the sandy clay or in the gravelly sand.

The 127 bones and fragments obtained belong almost entirely to the *Hippopotamus*, and probably to one animal.

List of *Hippopotamus*-bones.

Lower jaw (greater portion) with the two back molars and two canines. Five cervical, thirteen dorsal, four lumbar, and four sacral vertebræ.

Os innominatum.

Hind legs and feet :

Left femur, 21 inches long.

„ tibia, 15 inches long.

„ fibula (lower portion).

„ calcaneum.

„ cuboid.

„ metatarsal iv.

List (*continued*).

- Right fibula (lower portion).
- „ calcaneum.
- „ cuboid.
- „ metatarsal iv.
- „ astragalus.
- Fore foot :
- Left lunare.
- „ scaphoid.
- Portions of the 3rd or 4th right and left ribs and of other ribs, to the number of six or seven.

The majority of the bones are complete ; others, such as the os innominatum, were broken in course of extraction from the matrix, but have been pieced together. As a result there are about fifty complete or nearly complete bones. They are partly mineralized, are in a good state of preservation, and do not appear to have been rolled or knocked about.

Since so many parts of the animal's skeleton were found in a small area, it is probable that the body was stranded in an old channel of the river Derwent and quickly covered up by sand and clay—not, however, before the bones had been somewhat disturbed. The lower jaw was lying upside down, with the canines pointing north-west, the fibula and left iv. metatarsal, right astragalus and calcaneum were found together on the south ; and the left femur, right iv. metatarsal, some ribs, the five cervical and some dorsal vertebræ on the north. But by far the greatest number of bones, including the os innominatum, left tibia, dorsal, lumbar, and sacral vertebræ, part of the fibula, and right and left cuboid, was found on the east and north-east.

The large number of bones, their good state of preservation, and their only slightly disturbed positions, point to the conclusion that the carcass was deposited almost entire at the spot where the bones were found. All the evidence is against the supposition that the bones have been derived from an older deposit.

In addition to the *Hippopotamus*-bones were found part of the breast-bone of an *Elephas* and part of the femur of a *Rhinoceros*. The latter was near the head of the *Hippopotamus* and is more indurated than the bones of that animal. It is also scratched and worn. Many of the bones were taken to the Jermyn Street Museum, and, by the kindness of Mr. E. T. Newton, F.R.S., were compared with specimens there.

Since the above was written, Mr. Allen (who built the Inn at Allenton about 18 years ago) was interviewed by the writers. He says that some large bones were found when a well was dug and the cellars were excavated. They were not preserved, but were sold by the labourers and probably destroyed.

## PART II.—By R. M. DEELEY, Esq., F.G.S.

The deposits in and beneath which the mammalian remains were found occur on the inside edge of a gravel-terrace which covers a large area on the right side of the Derwent Valley below Derby. Its south-western boundary is more or less obscured by a variable thickness of unstratified, yellow, sandy clay containing pebbles. Masses of this pebbly deposit frequently penetrate 6 or 8 feet into the gravel, much as does the 'trail' of Southern England. At its inner edge the gravel terminates against rising ground, composed of Keuper Marl capped in places by Boulder Clay. The line of junction between the gravel and the Keuper commences on the south side of the breach made in the Derwent Valley escarpment by the Kedleston Brook. From here it skirts the lower portion of the Royal Infirmary grounds, crosses the railway near Osmaston Road, passes a few yards to the south-west of the section at Allenton, and then skirts the base of Chellaston Hill until the river-escarpment of the Trent, a mile north of Aston-on-Trent, is reached. Its north-eastern boundary is a continuous and steep escarpment about 18 feet above the modern alluvial plain of the Derwent.

This escarpment, starting near the Kedleston Brook breach, passes through the Midland Railway-station, and keeping on the north side of the London road, passes through Alvaston, Elvaston, and Aston, when it joins the corresponding escarpment of the Trent Valley.

Over the whole of this area the terrace is nearly flat, and slopes gently down the valley and towards the river. It is drained by two small streams, the larger of which rises near the spot where the bones were discovered. The point where the bones were found is indicated by a circle on the map, fig. 2 facing p. 502.

This portion of the ground I have contoured, so as to show the exact relationship between the Boulder Clay capping the ridge, the Derwent gravel to the N.E., and the low-level deposits of Sinfin Moor to the S.W. As the line of demarcation between the gravel, Keuper Marl, and Boulder Clay is more or less obscured by a sheet of 'trail,' the line marking the edge of the gravel is only approximately correct. The outcrops were, however, carefully followed by means of a boring-rod. The Boulder Clay was found to rest in all places upon Keuper Marl. It is a tough, bluish, sandy clay, with numerous striated limestone-boulders, and an abundance of coal, shale, gritstone, etc.

The gravel below the deposits in which the bones were found does not, therefore, either rest upon or pass beneath the Boulder Clay, but terminates rather abruptly against Keuper Marl.

A map published in this Journal, vol. xlii., p. 438, shows the whole of the terrace and also the surrounding deposits.

Fig. 3 (p. 502) is a section passing through the Allenton terrace. It commences in post-Glacial Trent Gravel, and then passes through High-level Trent Gravel, Sinfin Moor deposits, Pennine Boulder

Clay, High-level Derwent Gravel, and post-Glacial Derwent Gravel. An excavation on Sinfin Moor showed

	feet.	inches.
Black peat .....	1	2
Disintegrated shells .....	0	3
Stiff yellow clay .....	2	0
Shells .....	2	0
Quicksand .....	3	0
	8	5

Excavations showing the Allenton gravel are not very numerous. The best now open is situated a little to the east of Alvaston Church. The deposit is a red sand or sandy gravel, with beds of sandy clay containing pebbles. The pit is close to the edge of the escarpment. There is, consequently, very little left of the 'trail' at this point, denudation having been responsible for the removal of the fine material. Near the surface, however, the bedding is much broken and twisted, and in places all signs of stratification have been obliterated (fig. 4). A thickness of 10 or 11 feet of gravel is exposed, the lower portion only being comparatively free from contortions. The pebbles are chiefly quartzites, chert, cherty limestone, and gritstone. Limestone is not found in the clean gravel, having been dissolved by percolating water. Even in the beds of sandy clay the limestone has been almost wholly dissolved, nothing remaining in some places but a white chalky powder and hard core. A boring through the gravel passed into Keuper Marl and proved the thickness of the deposit to be 13 feet 8 inches.

Many excavations in the town of Derby and its suburbs have exposed gravel. In all cases the upper portion was seen to consist of contorted or unstratified yellow or red sandy clay with pebbles, or disturbed red gravel. An excavation for a cellar on the London road showed great rolls of red stony clay cutting down into the gravel to depths of 6 feet or more.

Although limestone is not plentiful in the gravel and sand near the edge of the terrace, it is abundant in the gravel

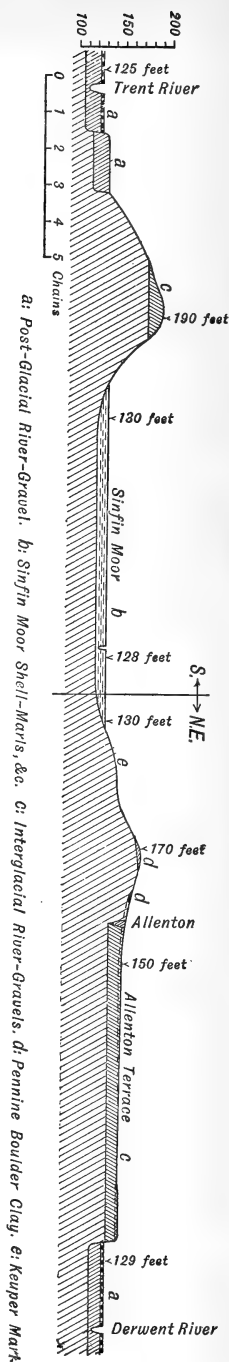


Fig. 3.—Section through Allenton Terrace, Sinfin Moor and the River Trent.

[To face p. 502.

**Fig. 2.**

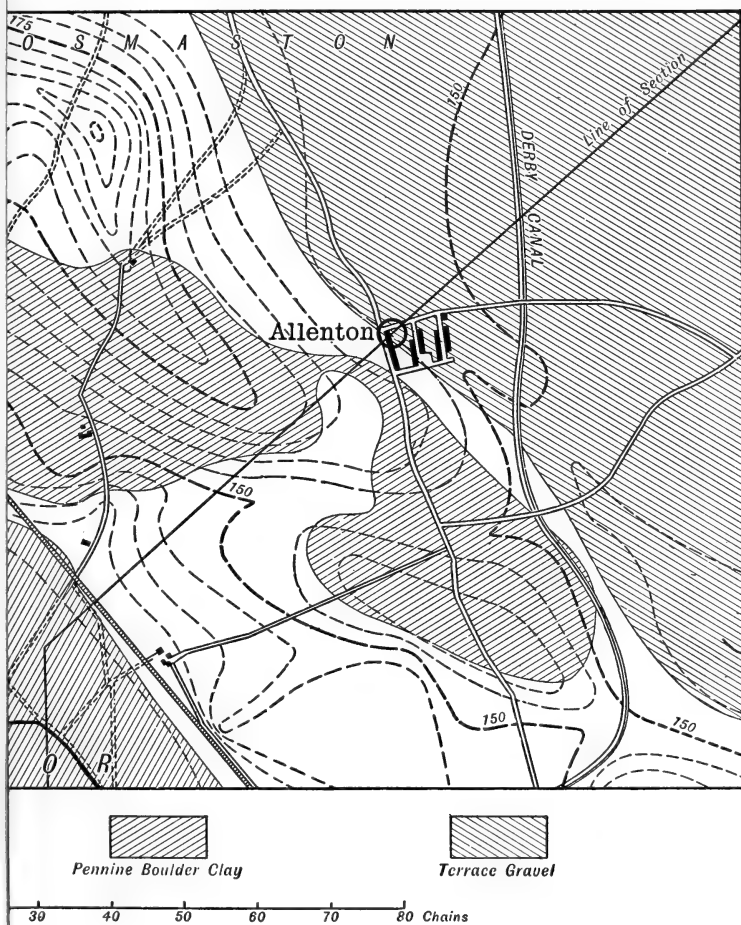
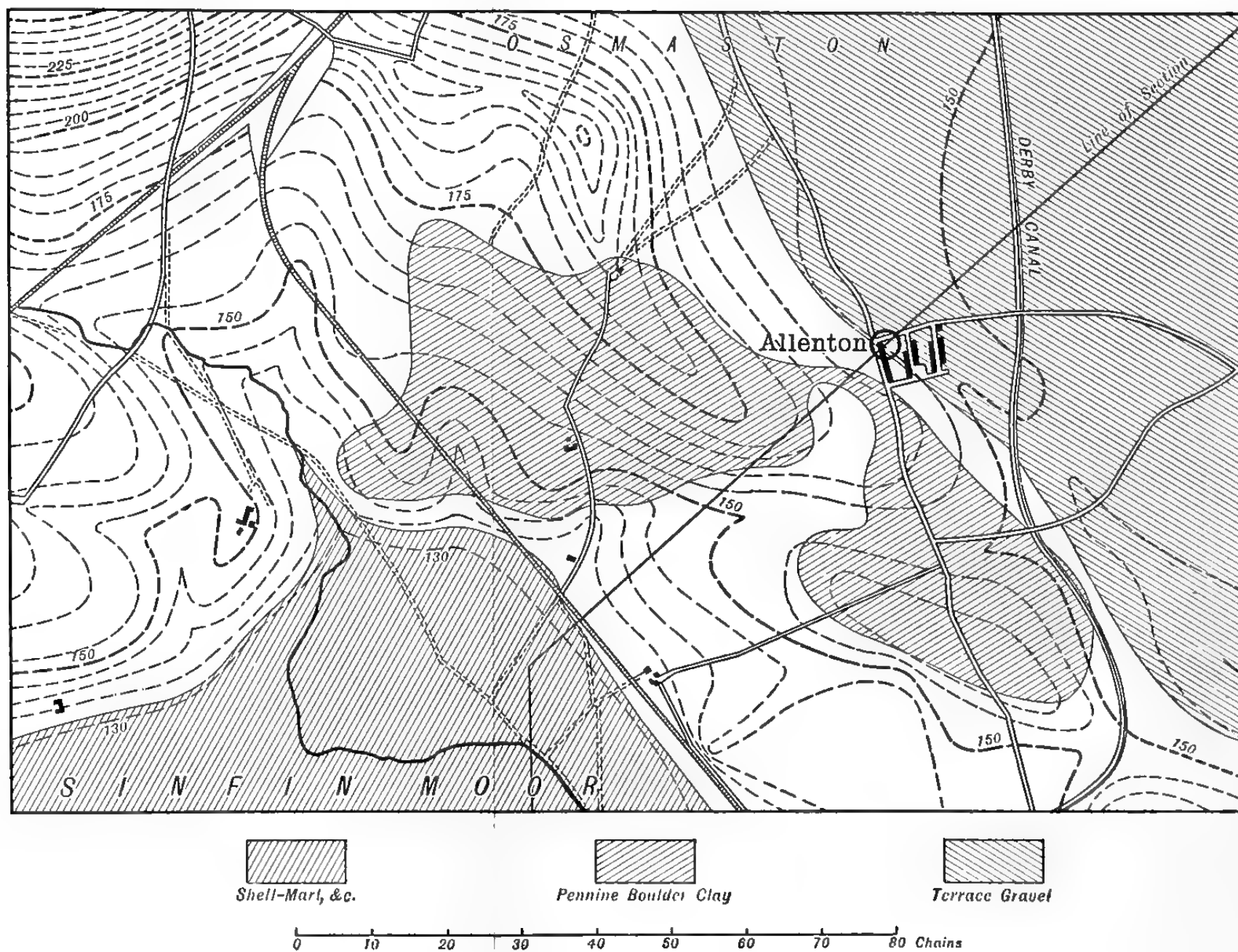






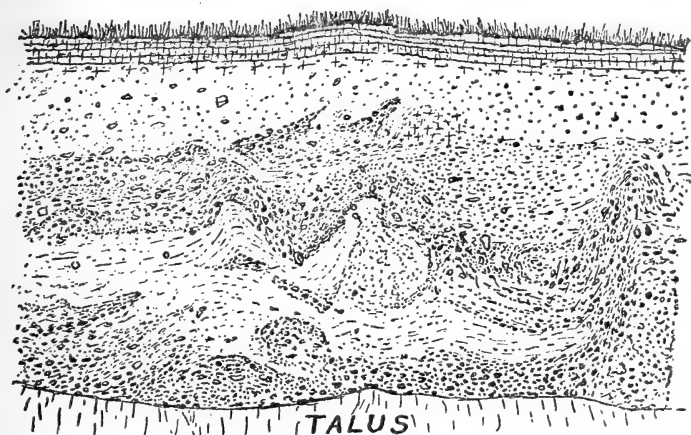
Fig. 2.





near Allenton on the inside boundary : a large number of limestone-pebbles having been found in a deep ditch south-west of Boulton. Under the nearly impervious covering of clay at Allenton, limestone-pebbles are numerous and fresh. Indeed, except as regards its weathered, disturbed, and stained condition, there is no marked difference between the terrace-gravel and the gravel of the lower alluvia plain.

Fig. 4.—*Interglacial river-gravel, Alvaston, near Derby.*



[Height of section = 7 feet.]

I have already stated the fact that the brook which drains the southern portion of the terrace, and debouches upon the modern alluvial plain of the Derwent near Thurlston, rises near Allenton : the contour-lines on the south-easterly portion of the map (fig. 2) being deflected when they reach the upper end of the trough. The section (fig. 3) shows this trough in the gravel filled with sand and clay. It runs approximately from N.W. to S.E., and was proved to exist by several borings which entered gravel a few yards to the north-east of the spot where the bones were found. This is confirmed by Mr. Allen, who informed us that wells sunk to the N.E. do not enter the bone-bed, but pass directly into the lower gravel, while wells to the S.W. enter red marl.

South-east of Allenton the soft trough-deposits have been denuded, and a depression has been formed along which the stream runs. It seems to have been a deserted loop of the Derwent, formed when the river ran at the level of the terrace.

In favour of the view that the dark sand and fine blue clay are of the same age as the terrace, the following additional considerations may be urged. In the first place, the limestone-pebbles found beneath the trough-deposits are in a better state of preservation than they are near the edge of the terrace, and appear to have been

preserved by the bed of nearly impervious clay which has covered them from the time they were first laid down. Secondly, the yellow upper clay with pebbles strongly resembles the 'trail' covering the terrace and Keuper at other points. However, it was only exposed for a few feet when the deep excavation was made, consequently its horizontal extension and variation, as it passes from Keuper to gravel, was not traced by open sections. Thirdly, such deposits as fill the trough are not being formed at the present time on the upper terraces. They are in fact being rapidly denuded from them, and are now only to be seen at points distant from the edge of the escarpment. The ridge separating Sinfen Moor from the gravel-terrace is also very low and narrow, and there is no stream running over the terrace which could have excavated the trough and then allowed it to be filled again. On the other hand, it might be urged that the trough was formed by the river immediately after the gravel was contorted, and that the river deserted the Allenton side of the valley soon after. This view, however, is scarcely so well in agreement with the facts.

At about the same level as the Allenton gravel-terrace a tongue of red gravel runs up the valley on the south side of Kedleston Brook. It is a red, indurated, sandy gravel which shows few signs of stratification, but here and there contains small lenticular masses of sand. The stones are sometimes large, generally well rounded, and lie at all angles in the red sandy matrix. They are mostly quartzites, but Keuper sandstone and flints also occur. The gravel is about 11 feet thick and rests upon Keuper.

The upper few feet of the Kedleston Valley deposit, where it meets the Keuper on the south-western boundary, shades off into red or yellow clay with pebbles. An excavation near Stretton's Brewery, close to the edge of the gravel, exposed clay with stones and sand, varying in thickness from 10 to 11 feet. It rested upon contorted and broken, not redeposited Keuper marl. At this point the whole deposit is 'trail' and 'underplight' rather than river or brook gravel, and indicates the action of disturbing forces which do not now act in the valley.

I have dealt at some length with the Allenton terrace (and its Kedleston extension) because the remarks made concerning it will apply, with little alteration, to several other extensive deposits of gravel and sand. Although we have called it a high-level terrace it is by no means the highest of its class, for such gravels are to be seen at higher levels along the course of the Trent as well as the Derwent. In some instances they reach a height of 70 or 80 feet above the alluvial plain of the river. In all cases they show contorted upper surfaces or intruded rolls of marl (Quart. Journ. Geol. Soc. vol. xlii. 1886, p. 467). They have already been described at some length in this Journal. Suffice it to say, therefore, that they are portions of alluvial river-plains which mark former levels at which the river ran, and which have escaped subsequent denuding

action by the rivers. The highest are, consequently the oldest, and the lowest the most recent.

The Allenton gravel forms one of the lowest of the upper series of terraces, and, since it was spread out by the river, the Derwent has deepened its valley from 15 to 20 feet, and by excavating horizontally as well as vertically, and leaving behind it a bed of gravel and brick-earth, has formed a broad low-level alluvial plain.

The question of the relationship of the river-gravels to the surrounding deposits merits more detailed notice, for there are considerable masses of silty boulder-clay in their immediate vicinity.

The elevated land to the south and south-west of the Allenton terrace is capped by two varieties of boulder-clay and associated gravel and sand. The oldest deposit, the Pennine Boulder Clay, is a stiff, blue, silty clay containing numerous well-striated and polished rock-fragments from the Pennine Chain. These boulders may have, in part at least, come down the Derwent and Wye valleys, and in part by way of Staffordshire, Cheshire, and Lancashire from the Yorkshire Fells. Flints are absent except in the 'trail.' A mass of this boulder-clay spreads as an irregular patch over the low ridge separating the Allenton terrace from the depression of Sinfin Moor, as shown in the map (fig. 2). As already pointed out, it rests upon Keuper Marl. The same boulder-clay is exposed in an open section at Sheldon Wharf, a little farther south. For a description of this section, see Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 449. It here passes beneath another and newer boulder-clay, namely, the Great Chalky Boulder Clay.

At Spondon, on the opposite side of the valley, the hill is covered by another mass of Pennine Boulder Clay, which reaches a thickness of more than 60 feet.

The Great Chalky Boulder Clay covers the greater part of Chelaston Hill to the south of Allenton, where it attains a great thickness. Unlike the Pennine Boulder Clay, the Chalky Boulder Clay contains an abundance of rock-débris only to be found *in situ* to the east of the Pennine Chain. The boulder-clay is capped by a thick bed of clean, stratified, current-bedded sand at a height 256 feet above Ordnance-datum, or 130 feet above the alluvial plain of the Derwent. The sand is about 17 feet thick, and does not resemble river-gravel.

Boulder-clays of both kinds have been found capping the high grounds and river-escarpments of the Trent and its tributaries. At some points they come down to levels within a few feet of the flood-level of the Trent. They were deposited in the pre-Glacial river-valleys which they filled to a depth of at least 100 feet; and when the rivers again commenced to flow, on the disappearance of the ice, their first task was to clear away the Glacial deposits. The high-level terraces were formed while this was taking place. Indeed the pebbles and boulders which they contain are, in many instances, only such as could have been derived from the boulder-

clays of the area. The patches of boulder-clay now remaining are merely portions, which denudation has spared, of great sheets which once nearly filled the lower grounds of the Trent Basin.

The alluvial plain through which the Trent, and the lower reaches of many of its tributaries, run, consists of a thick bed of gravel, for the most part covered by a layer of brick-earth. Sections have been opened out in it at many points.

An excavation, for a gasometer, to the east of the Midland Railway Station, Derby, passed through brick-earth and then gravel and sand. Limestone and gritstone were plentiful. A few flints were seen. The deposit was regularly stratified, and false-bedded, and quite undisturbed, nothing in the nature of 'trail' being seen at or below the surface.

The ballast-pit (now full of water and known as Trent Lake) exposed a fine section of modern Trent gravel. Here also the 'trail' was absent, the upper surface being quite undisturbed and the gravel, sand, and brick-earth regularly stratified from the brick-earth to the bottom of the gravel.

At Colwick, near Nottingham, another pit exposed these modern gravels. Here the brick-earth was about 2 feet thick. The surface showed no trace whatever of disturbance, and the gravel and sand were well stratified and false-bedded.

In all cases where the newer deposits have been exposed in section, 'trail' and 'underplight' were quite absent, the surface-ports being quite free from contortions. The low-level gravels of course show signs of root-penetration, the sand and pebbles being bleached or discoloured by the action of organic acids, etc., but this cannot be confounded with 'trail,' neither can the subsidences resulting from the action of underground denudation.

Certain physical features of the valleys also deserve notice.

Wherever the modern alluvial plain is bounded by a high-level gravel-terrace, or other resisting rock, the boundary-line between it and the alluvium is marked by a steep escarpment. Such a continuous low cliff may be traced through Derby, Alvaston, Elvaston, Aston-upon-Trent, Weston-upon-Trent, and thence along the northern side of the Trent Valley as far as Egginton. It then turns up the Dove Valley. It may also be traced up the Trent Valley beyond Burton.

On the northern side of the Derwent Valley the escarpment is continuous between Borrowash and Long Eaton. Passing down the Trent it commences again at Beeston, and on the right bank of the river it may be traced from Gamston in the direction of Newark.

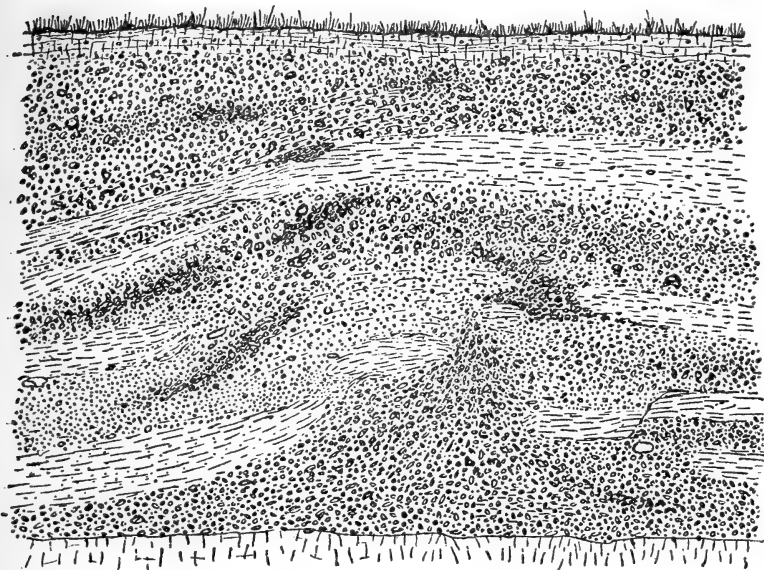
Where streams enter the main valley, the terraces are breached, and the brooks run in V-shaped hollows.

These escarpments separate the disturbed from the undisturbed deposits, the high-level formations only showing the 'trail.'

At one time, no doubt, the two upper terraces at Weston-on-Trent (Quart. Journ. Geol. Soc. vol. xlii. 1886, p. 469) faced the river with steep slopes also, but their edges have in some way been

smoothed off, and it is difficult to resist the conclusion that the agent which contorted the gravels hereabouts (produced the 'underplight')—fig. 5—also obliterated the terraced aspect of the ground.

Fig. 5.—*High-level river-gravel, Weston-on-Trent.*



[Height of section = 5 feet.]

The excavation of the Sinfin Moor area is also a difficulty. It is an almost perfectly flat plain, about 1 square mile in area, covered by more than 8 feet of shell-marl, peat, and fine clay. The surface is at about the same level as the alluvial plain of the Derwent (see fig. 3, p. 502), and only about 4 or 5 feet above the low-level plain of the Trent. It cannot have been excavated by running water, for it was once a lake which had been drained by the deepening of the Trent Valley. Nor does it show any sign of having been produced by earth-movements. The Allenton terrace, for instance, does not appear to have been locally depressed, although the gravel approaches to within  $\frac{3}{4}$  mile of the hollow, and is only separated from it by a low ridge. On its southern side Sinfin Moor is separated by a much higher ridge (also capped by gravel running at definite levels) from the Trent Valley. The moor waters drain into the Trent through a narrow short valley between Chellaston and Swarkstone. The depression could not well have been in existence when the Allenton terrace-gravels were being formed, for if it had the lake would have been a deep one, and no high-level terraces or deltaic deposits have been found to support

the view. Nor could it have existed when the high-level gravel on the northern escarpment of the Trent, shown in section (fig. 3, p. 502), was being deposited; indeed, it has clearly been excavated at a comparatively recent date, and was once a shallow lake, which has since been drained by the deepening of the Trent Valley. It seems to have been formed by a glacier at the same time as the 'trail,' or, which is much less likely, by the removal of a soluble bed in the Keuper Marl below.

We are now in a position to discuss the age of the bone-bearing deposits.

Although in no case have we found any of the high-level gravels resting upon either the Pennine or the Chalky Boulder Clay, from the positions which the gravels occupy on the sides of the valleys and the presence in them of flint from the Boulder Clays, it may be safely concluded that all the river-gravels were deposited at a subsequent date. It only remains, therefore, to show how they are related to the gravels, etc., of the lower plain, and to decide whether they are of Interglacial or post-Glacial age.

It is generally conceded that glaciers have never reached those portions of England that lie to the south of the Thames Basin. There we have no true boulder-clays. But even thus far south deposits are to be found which it is difficult to account for, except on the supposition that the climate was at one time very cold. When such surface-deposits were being formed, other portions of England were being glaciated, and, therefore, such deposits belong to a British Glacial Period. Any period of cold which was sufficiently severe to cause glaciers to appear in Britain we may call a 'glacial period,' and any period intermediate between the two glacial periods an 'interglacial period.' Whether it is wise or the contrary to retain a classification connoting a physical change in the conditions under which the deposits were formed is open to argument, but such considerations need not influence us in settling the relative ages of the particular deposits with which we are dealing. Consequently, whether the 'underplight' and trail be due to an agent owing its existence to a change of climate, or to some other cause, we may with confidence assert that they are now being denuded from most if not all the areas in this country on which they were at one time formed, and are typical of a particular epoch or epochs of the Pleistocene Period.

Just as it has been suggested that the formation of certain rubbly deposits, etc., which have been formed in the South of England must be attributed to the action of frost, heavy masses of ice or snow and of floods on a frozen ground, so I would attribute the formation of similar deposits in the Midlands to similar agencies. But some of the surface-phenomena presented by the gravels, etc., which have been described above can, I think, only be explained on the assumption that, at a comparatively recent period, and after the rivers had excavated their valleys to a depth of within 15 or 20 feet of their present levels, an ice-lobe from the basin of the Irish Sea



passed down the Trent Valley for some distance to the east of Nottingham.

In the South of England and in certain areas on the Continent, the flexures of the 'underplight' seem in all cases to bear a very close relationship to the slopes upon which they occur. According to Mr. Spurrell, it is 'the result of a steady movement, a flow or push in certain directions in accordance with the slopes on the surface of the land: the amount of slope determining the direction being often very slight.' In the area of the Trent Basin under consideration the phenomena which we are discussing do not, in a large number of cases, bear out the contention that the flexures may result from the flow of surface-deposits down slopes, for they occur on extensive flat areas, and the trend of the furrows and ridges is such, in the majority of instances, as would indicate a movement from the west or thereabouts rather than down the adjoining hill-sides.

We must, I think, admit that 'trail' and 'underplight' may have been formed under slightly different conditions in different districts, and that the conditions which obtain or have obtained in each district must be deduced from the appearance of the local deposits.

Otherwise, how are we to explain the fact that indurated masses of gravel such as those at Allenton, Weston, Beeston, Lenton, and Gamston, and also other surface-deposits, have been forcibly puckered and bent to depths of from 8 to 12 feet from the surface? Not on sloping surfaces, be it remembered, but on approximately flat areas of considerable extent. That such surface-features are not now being produced may be seen from all the sections of post-Glacial gravel, loam, soil, etc., which have been described. But it is not only the gravels which have been contorted and disturbed in this way. The surface of the older rocks, where it can take and preserve such features, is affected. Sometimes the contortions or waves terminate abruptly at the surface-soil as though they were the remnants of a thicker deposit, the upper portions of which have been removed. That the contortions are not due, in some instances at any rate, to the slipping of the surface-layers by the direct action of gravity is proved by the fact that they often occur on level ground. Indeed, upon the steeper slopes of the area deposits of 'trail' and contorted surfaces are generally not to be found, for denudation has there acted so energetically that all traces of such surface-action have disappeared.

We are, therefore, constrained to admit, it seems to me, that the upper terraces covered by the 'trail' or showing disturbed surfaces are of Interglacial age. That the Allenton terrace is of Interglacial age was stated in a paper read before this Society in 1886, and all subsequent work has tended to confirm me in this opinion. The discovery of *Hippopotamus*, *Rhinoceros*, and *Elephas* in the gravel supports this view rather than militates against it.

## DISCUSSION.

The PRESIDENT congratulated the Authors on their remarkable find, and on the splendid specimens exhibited by them. The mode of preservation of the fossil remains reminded one of that of the Endsleigh Street mammoth-remains, and in both cases it was no doubt attributable to the covering of the deposits by a clayey layer. Indeed, as a whole, the conditions much resembled those of the Thames Valley: there, as in the Derwent Valley, were plateau-gravels and low-level gravels. He enquired whether certain deposits marked on the section exhibited were not originally one sheet of gravel, rather than several distinct terraces. If Mr. Deeley's view of the Interglacial age of the fossiliferous deposits was correct, we had here another point of resemblance with the Thames Valley deposits.

Mr. REID congratulated the Authors, and hoped that they would continue to search the deposit for further evidence of the climatic conditions. He doubted whether surface-contortion in gravel was sufficient evidence of glacial action or of an Arctic climate.

Mr. E. T. NEWTON also spoke.

Mr. DEELEY, who replied on behalf of Mr. Arnold-Bemrose and himself, thanked the Fellows who took part in the discussion for the considerate way in which they had criticized some of the points raised in the paper. At so late an hour he thought that it was impossible to discuss the question of the origin of the 'trail'; he therefore contented himself with remarking that, just as Mr. Reid had held with regard to the Bagshot Sands, it was necessary to examine the ground mile by mile, and map and compare the deposits with each other, so in the case of the 'underplight' it was necessary to take into account its local peculiarities in order to form a correct conclusion as to the agent which produced it. In reply to the President's question concerning the relationship between the various high-level terraces of the Trent and Derwent, a section through the gravels of Weston-on-Trent was instanced. Here there are three high-level terraces, the escarpments of the two upper ones seeming to have been obliterated by the agent which produced the flexures of the 'underplight.' In the operation of excavating the valley the erosive action of the stream exerted itself both horizontally and vertically, and the river always left behind it a sheet of gravel. Each terrace is consequently a fragment, which has escaped denudation, of the gravel-plain formed when the river ran at that particular level, the highest being the oldest, and the lowest the most modern: the connecting gravel-areas which separated the terraces having been denuded as the rivers wandered from side to side of their valleys.

30. *The LINGULA-FLAGS and IGNEOUS ROCKS of the NEIGHBOURHOOD of DOLGELLY.* By PHILIP LAKE, Esq., M.A., F.G.S., and S. H. REYNOLDS, Esq., M.A., F.G.S. (Read May 27th, 1896.)

## [PLATE XXIV.—Map.]

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## I. INTRODUCTION.

THE magnificent section displayed in the precipitous northern face of Cader Idris has attracted the attention of many geologists, and has proved so seductive that the lower-lying country to the north has been almost neglected. It is with the latter that we are concerned. Here the *Lingula*-Flags are well developed, and are associated with contemporaneous volcanic rocks and with remarkable intrusive masses of diabase.

But little has yet been published concerning these rocks. Belt<sup>1</sup> in his classical paper upon the *Lingula*-Flags has dealt with the general sequence in the district, and refers to several localities in the neighbourhood of Dolgelly. Cole and Jennings<sup>2</sup> have examined the rocks immediately south of the area covered by our map, and they were led to believe that the volcanic eruptions of this region began at least as early as the Tremadoc period; but, as they remark, the point requires further investigation. We are able to justify their belief, for we have discovered a well-defined band of andesitic lava in the *Lingula*-Flags themselves.<sup>3</sup>

Several references to the region will also be found in the Geological Survey Memoir on North Wales<sup>4</sup>; and the account of the *Lingula*-Flags in the Palæontological Appendix is in this respect of particular interest.

<sup>1</sup> Belt, 'On the "*Lingula*-Flags" or "Ffestiniog Group" of the Dolgelly District,' Geol. Mag. 1867, pp. 493-495, 536-543; *ibid.* 1868, pp. 5-11 & pl. ii.

<sup>2</sup> Cole & Jennings, 'The Northern Slopes of Cader Idris,' Quart. Journ. Geol. Soc. vol. xlv. (1889) pp. 422-439.

<sup>3</sup> [It should be mentioned that Messrs. Salter and Hicks have already recorded contemporaneous trap from the *Lingula*-Flags (Quart. Journ. Geol. Soc. vol. xx. 1864, p. 241); and that Dr. Hicks finds volcanic material in the Menevian and even at the boundary between the Caerfai and Solva beds (Geol. Mag. 1894, p. 405).—July, 1896.]

<sup>4</sup> Ramsay, 'The Geology of North Wales,' Mem. Geol. Surv. vol. iii. 2nd ed. 1881.

## II. DESCRIPTION OF THE AREA.

The area with which this paper deals lies south and west of Dolgelly, between the Arthog road and the hill called Mynydd Gader, which stands in front of the precipices of Cader Idris.

The town of Dolgelly stands in the valley of the Wnion, a short distance above the point where that river enters the broad and picturesque estuary of the Mawddach. South of the river the ground rises generally, but not uniformly, to the west of the Cader Idris ridge. From the eastern end of the town a deep and rather narrow valley, cut by the Afon Aran, runs in a southerly direction into the rising ground; and from Pandyr-odyn, a short distance west of Dolgelly, another stream has carved a second valley which stretches away to the S.W. along a line of fault, which we shall call the Dolgelly fault.

Between these two valleys, immediately south of the town, the ground rises steeply to a broad and rocky plateau occupied by a mass of diabase; and then sinks slightly to a lower and more level plain, which stretches across the map from east to west, and on which is built the house called Rhydwen. In the eastern part of this plain the Nant Ceunant cuts for some distance a deep and narrow gorge along a line of fault; and from this fault the ground again slopes up, with some inequalities, to the foot of the diabase crags of Mynydd Gader.

West of the Dolgelly fault, the contour of the ground, so far as our map extends, is nearly the same as it is on the east. South of the Arthog road there is a steep rise which gradually becomes gentler as we approach the top of a great rounded mass of diabase; and on the southern side of the diabase the surface falls to a tract of marshy land—the continuation of the plain of Rhydwen.

In the N.W. corner of the map, the diabase is narrow and makes only a low and unimportant ridge, while the highest ground is formed by the *Lingula*-Flags north of it.

## III. GEOLOGICAL STRUCTURE.

The area examined is divided into four parts by three nearly parallel faults running from S.W. to N.E., the most important of which lies in the valley of Llyn Gwernan and Pandyr-odyn.

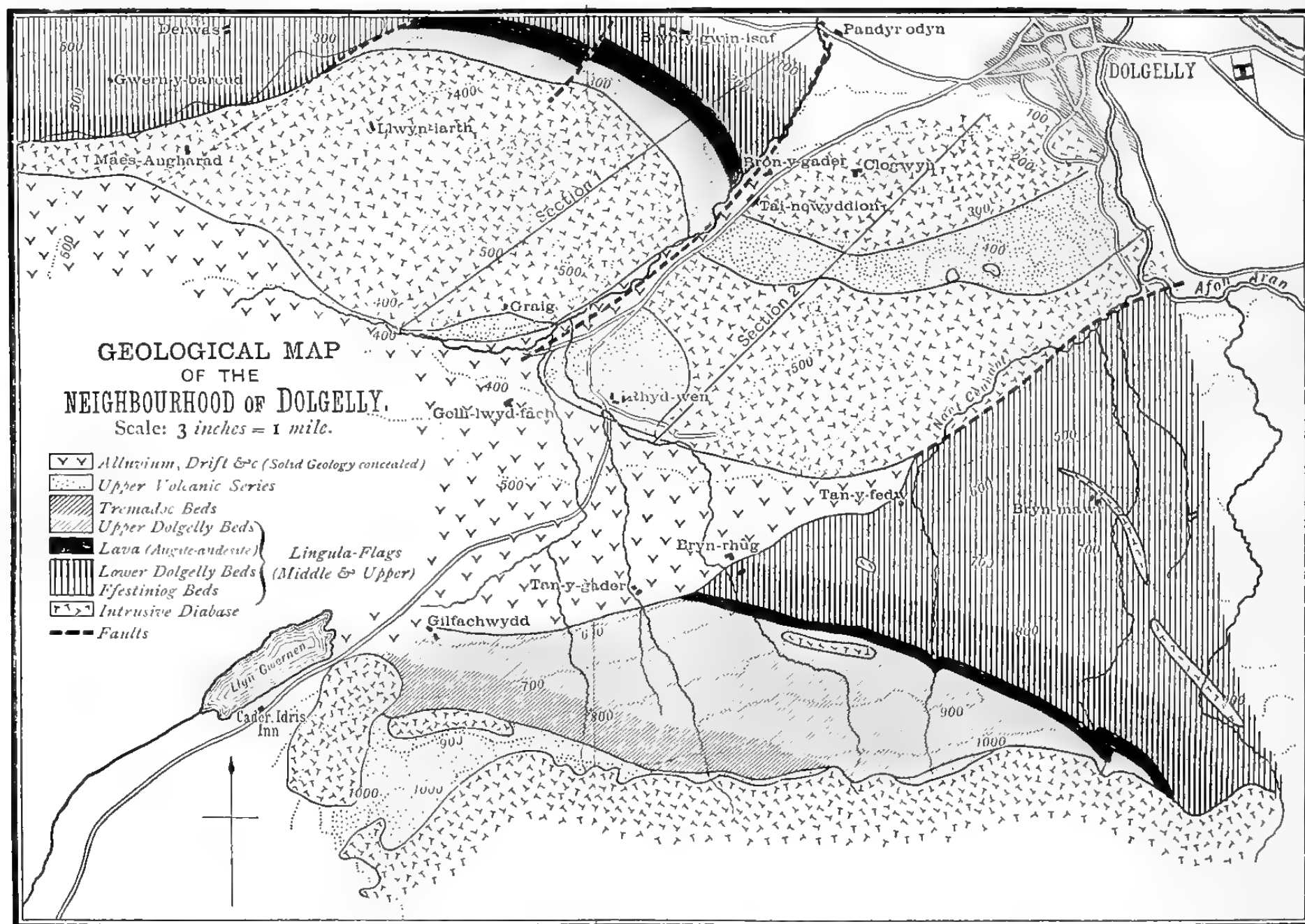
Another fault, south of Dolgelly, follows the general direction of the lower part of Nant Ceunant, and brings the diabase on the north against the Middle *Lingula*-beds on the south. Along the line of this fault there is a zone of rock crushed into a kind of stiff green clay. It is visible in the bed of the stream itself, but is still better shown in the cliff which forms the right bank of the Afon Aran just above its junction with the Nant Ceunant.

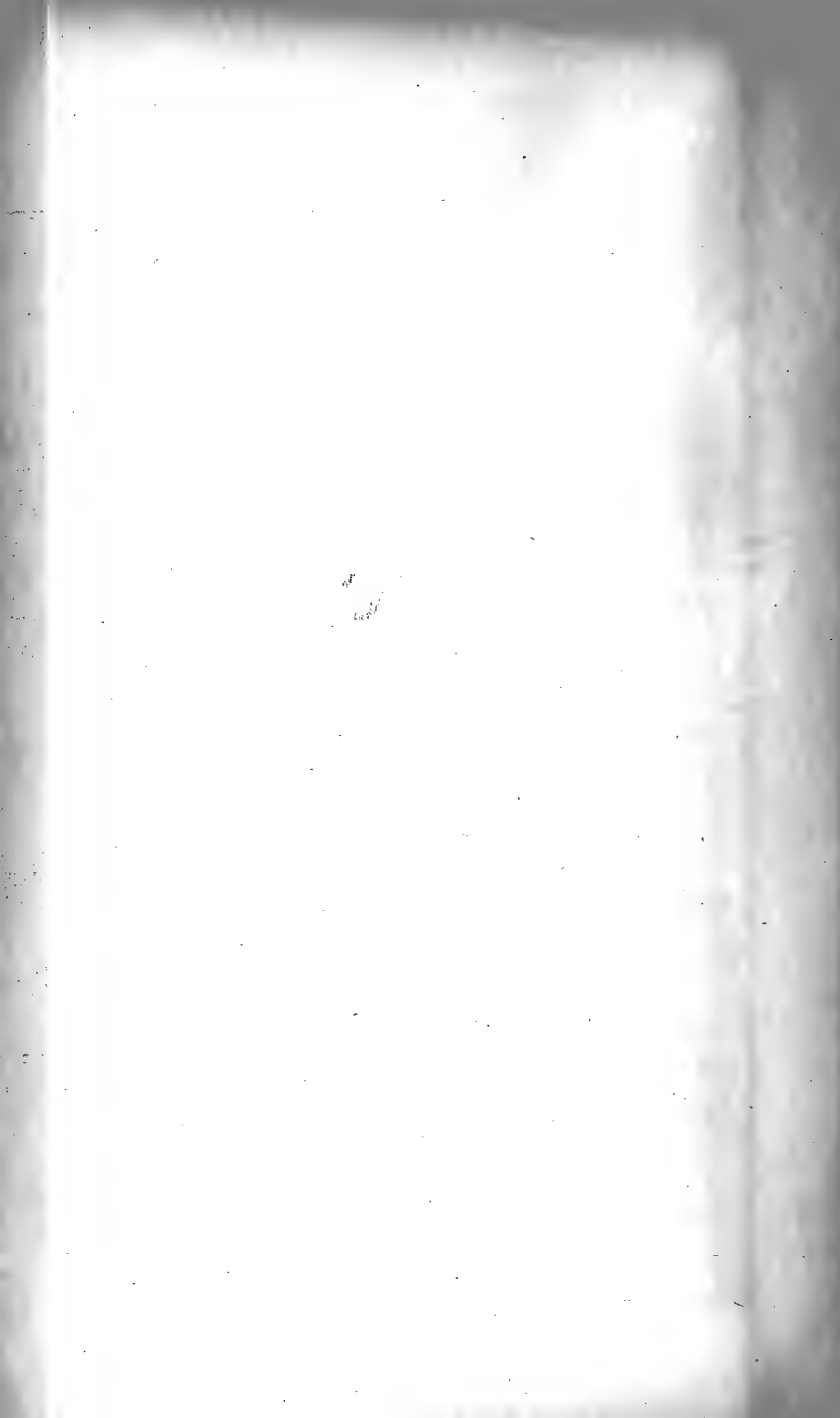
The third fault coincides for a short distance with the stream that flows east of the farm called Derwas, in the north-western corner of the map. It brings the black slates and the lava-band of Bryn-y-gwin woods into contact with the Middle *Lingula*-Slates of Derwas and Gwern-y-barud, the beds on both sides striking nearly east and west. This we may call the Derwas fault.

[To face p. 512.











Lastly, we have some reason to believe that a fault runs nearly from north to south just outside our map on the east; but our evidence is not complete, and in any case the fault does not affect the area actually described.

In the north-western corner of the map the dip is southerly. The Middle *Lingula*-beds are well exposed and are overlain, just along the northern margin of the diabase, by a band of darker slates belonging to Belt's 'Dolgelly Group.'

The Derwas fault clearly has its downthrow on the south-eastern side, and brings the black slates and lava-band of the Upper *Lingula*-beds into line with the Middle *Lingula*-beds on its north-western side. But it does not affect the inclination of the beds, for the lie of the lava in the Bryn-y-gwin woods shows that the general dip is still southerly. This is maintained even on the other side of the great diabase mass, for near Graig we find slates and ashy beds, the latter showing a dip of about  $32^{\circ}$  due S.

East of the Dolgelly fault, and north of Nant Ceunant, most of the surface is occupied by diabase; but the ashes and other stratified deposits which form the band stretching across towards the Afon Aran still keep the southerly dip.

South of the Nant Ceunant fault, however, there seems to be a marked change in the general strike. On the northern slopes of Mynydd Gader the band of lava in the Upper *Lingula*-beds runs about W.N.W.-E.S.E., indicating (since the surface slopes down from south to north) that the beds dip towards the south-west. In the Middle *Lingula*-beds, however, north-east of this lava-band, there is considerable variation, and south-east of Brynmawr the dip is due west.

#### IV. THE STRATIFIED ROCKS.

##### (a) The Slopes of Mynydd Gader.

*Nant Ceunant*.—The fullest and clearest section of the sedimentary strata in this district is to be seen in Nant Ceunant, a tributary of the Afon Aran.

About 250 yards N.E. of Tan-y-fedw the diabase, which forms most of the bed of the stream up to this point, gives place to bluish slates, interstratified with hard gritty bands. These continue up the stream for some distance, and contain *Lingulella a Davisii* in abundance. They belong to Belt's 'Ffestiniog Group.'

Gradually the slates become darker and darker in colour, and cease to yield *Lingulella*; but a solitary fragment of a trilobite was discovered. A narrow band of volcanic ash or lava (not shown in the map) occurs; and then follow more dark slates extending to a distance of  $\frac{1}{4}$  mile south of Tan-y-fedw, where they are succeeded by the thicker bed of andesitic lava shown in the map.

This lava is followed by a series of very black fissile slates with a black streak, which continue without much change up to the crags of Mynydd Gader. But at one point we came across a small band of ashy-looking rock, which appears to strike in quite a different

direction from the beds below. It was, however, visible only in the stream. Probably better exposure would disclose other small complications; but the general structure of the slope is clear.

*Bryn-rhug*.—The chief bed of lava just mentioned can be clearly traced over the fields both S.E. to the diabase of Mynydd Gader, and N.W. to the stream at Bryn-rhug; and it affords a good datum-line for correlating the section in Nant Ceunant with that at Bryn-rhug.

At Bryn-rhug the lava forms the top of a waterfall of considerable height, and the beds immediately below it have been quarried, so that the conditions are more favourable for examination than in Nant Ceunant. The beds in the quarry are dark hard slates, containing numerous fossils referable to the following species:—*Orthis lenticularis*, Dalm., *Agnostus*, *Leptoplastus*, and *Parabolina spinulosa*, Wahl. (one specimen). They belong to Belt's 'Dolgelly Group.'

Above the lava we get the same black fissile slates as in Nant Ceunant.

*Tan-y-gader*.—When we reach the next stream on the west, the one which flows past Tan-y-gader, the lava has sunk down into the level alluvial plain, and the first rocks which are visible, close to the farm, are the black fissile slates. Slaty beds continue in the stream up to the diabase; but they gradually become paler in colour and firmer in texture. A fragment of a trilobite was found some distance above Tan-y-gader; and near one of the small tributaries close to the diabase, *Lingulella lepis*, Salt., was discovered, not actually *in situ*, but in blocks which clearly belonged to the neighbouring rocks. This is a Tremadoc form.

*Gilfachwydd, etc.*—Similar slates occupy most of the lower slopes of Mynydd Gader west of this stream, and a little south of Gilfachwydd they have yielded *Dictyograptus flabelliformis*, showing that the higher beds of this slaty series belong to the Tremadoc.

In the upper part of one of the streams between Tan-y-gader and Gilfachwydd, the slates are succeeded by a band of rhyolite, which may be traced westward as far as the small diabase-mass south of Gilfachwydd.

Similarly in the stream which flows past Gilfachwydd, the slates which form most of its bed, and which near the farm have yielded *Dictyograptus*, are succeeded on the south by a mass of rhyolitic lavas and ashes.

*General sequence*.—The general sequence of the beds, therefore, on the northern slopes of Mynydd Gader, from the Nant Ceunant westward, is as follows (in ascending order):—

LINGULA- FLAGS (MIDDLE AND UPPER).	FFESTINIOG.	Bluish slates with grit-bands, containing <i>Lingulella Davisii</i> and passing up into
		Dark slates, with <i>Orthis lenticularis</i> , <i>Leptoplastus</i> , etc. (at Bryn-rhug).
	DOLGELLY.	Andesitic lava.
		Black fissile pyritous slates, which appear to pass up into
TREMADOC.		Dark grey slates, with <i>Lingulella lepis</i> , <i>Dictyograptus flabelliformis</i> .
		Rhyolitic lava.

It may be remarked here that Belt attaches much importance to the black streak characteristic of his 'Upper Dolgelly Group.' Generally speaking, the slates above the andesitic lava, and no others, possess this peculiarity; but we have not been able to draw a definite line between them and the somewhat paler-coloured beds above.

*East of Nant Ceunant.*—We commenced our description with the Nant Ceunant because here the general succession is most clearly shown; and we have described the character of the rocks west of that stream. It is now necessary to give some account of those which lie farther east.

The lava-band may be followed from Nant Ceunant with very little interruption until it reaches the diabase of Mynydd Gader; and for the greater part of this distance it is well exposed, forming the crest of a spur which juts out from the main ridge of Mynydd Gader. The black slates below the lava are also very clearly seen; and in the streams which run down from Mynydd Gader, east of Nant Ceunant, they are underlain by slaty and gritty beds which in many places yield *Lingulella Davisii* in abundance, and clearly belong to Belt's 'Ffestiniog Group.' These beds become more gritty lower down.

Similar beds occupy the greater part of the space between the black slates and the Nant Ceunant fault, and are visible at intervals over the whole of this area. They are particularly well exposed, and *Lingulella* is particularly abundant, in the hill which lies west of Brynmawr. They also occur in the wood between Tan-y-fedw and Bryn-rhug.

Another point in connexion with the Mynydd Gader slopes requires notice. The band of lava which lies above the *Dictyograptus*-beds in the west follows the base of the diabase as far as the head of the Bryn-rhug stream; and a mass of similar rock occurs even as far east as Nant Ceunant. It is clear, however, that in its eastern part this lava does not strike in the same direction as the beds below, but lies across their edges. We believe that it is not here in its natural position, but has been dragged into its present situation by the diabase.

### (b) West of the Dolgelly Fault.

*Bryn-y-gwin Woods.*—A sequence similar to that in Nant Ceunant, but by no means so complete, is developed along the northern border of the great mass of diabase west of the Dolgelly fault. The stream which flows past Pandý'r-odyn runs nearly along the line of the fault, and on its left bank the same beds are exposed as in the woods farther west. The right bank, on the other hand, is formed, in part at least, by the ashy rocks which occur in the hill on the east.

Leaving the latter out of consideration for the present, we find dark bluish slates forming the bed of the stream at Pandý'r-odyn. These pass up gradually into black shaly slates which extend

almost continuously up to Bron-y-gader. The only fossil which we discovered was a fragment of a trilobite; but Belt states that he found '*Dictyonema fenestrata*, Salt.,' below Bron-y-gader.

Above Bron-y-gader these black slates are succeeded by a band of lava; and beyond this no further exposures are visible in the stream until we reach the diabase.

But the band of lava is seen again in the hill on the west, in the path near Bryn-y-gwin farm; and farther west still it is exposed for a considerable distance in the woods of Bryn-y-gwin. Everywhere it is underlain by black slates similar to those in the stream, and overlain by a second band of black slates, in which we discovered *Obolella Sabrinæ*, Call., at two localities. The upper part of the second band close to the diabase sometimes contains fragments of ash.

The band of lava which is shown upon the map is, like that in Nant Ceunant, an andesite; and, as in Nant Ceunant, we have slight indications of the existence of a smaller volcanic band below it. About 350 yards above Pandyr-odyn a small ashy looking band crosses the stream; and a somewhat similar band is rather badly exposed at the farm of Bryn-y-gwin.

Although in the absence of better palæontological evidence, there is no absolute proof that the beds in this area are the same as those in Nant Ceunant, yet the correspondence between the two sequences is so close as to leave little room for doubt; and we are justified in considering the Bryn-y-gwin lava to be the continuation of that in Nant Ceunant.

*West of the Derwas fault.*—West of the little valley where the lava and black slates of the Bryn-y-gwin woods abruptly cease, the predominant rocks are bluish slates with bands of grit. East of Derwas they dip S.E. or S.S.E., while near Gwern-y-barcud they dip due south. Close to the latter farm we found *Lingulella Davisii*.

These beds are succeeded, as in Nant Ceunant, by darker coloured slates, which lie along the northern margin of the diabase. In one of the small woods a little west of Maes-angharad they yielded *Parabolina spinulosa* in abundance, and one specimen which looks like *Arionellus*.

The slates with *Lingulella Davisii* are clearly the equivalents of those near Tan-y-fedw, and the beds with *Parabolina spinulosa* probably lie at a somewhat lower horizon than the fossiliferous slates of Bryn-rhug. The latter are close to the lava-band, and seem to be separated from the *L. Davisii*-beds by a greater thickness of deposit.

### (c) Upper Volcanic Series.

On the slopes of Mynydd Gader the beds which contain *Lingulella lepis* and *Dictyograptus flabelliformis* are succeeded, as already shown, by a band of rhyolite; and towards the western end of the hill this is followed by a considerable area of volcanic rock which we have not yet examined in detail.

On the southern side of the diabase-mass in the north of the map, west of the Dolgelly fault, a similar series of volcanic rocks is exposed, together with a certain amount of slate. They dip towards the south, and appear to be the continuation of the sequence of which the lower members are exposed on the northern side of the diabase. The thickness of the black slate visible above the lava-band in the Bryn-y-gwin woods is very much less than above the equivalent band on Mynydd Gader; but probably the upper beds of the slates are concealed beneath the diabase.

A series of ashes and tuffs of rhyolitic character is exposed in the road and copses north of Rhydwen; and a belt of ashes, agglomerates, etc. runs from east to west between the two patches of diabase immediately south of Dolgelly. The general dip in this belt is southerly. Similar rocks form the bed of the Afon Aran near Dolgelly and part of the eastern bank of the stream above Pandy'r-odyn.

It is only on Mynydd Gader that the age of these volcanic beds has been proved by palæontological evidence. There they undoubtedly lie above beds which contain *Dictyograptus flabelliformis*, and therefore they cannot be older than Tremadoc.

But we cannot be far wrong in assigning a similar or later age to the other patches, for nowhere in this district have we found any evidence of so great a series of ashes and lavas among the beds below the Tremadoc.

It may be remarked here that in Aber Gwynant, a stream which lies beyond the western boundary of our map, there is a sequence not unlike that on the slopes of Mynydd Gader; and here again it is not till we pass the *Dictyograptus*-slates that we reach any extensive series of volcanic rocks.

So far as we have examined with the microscope the rocks here spoken of as the Upper Volcanic Series, we find that they are rhyolitic lavas, ashes, and tuffs; while the band of lava in the *Lingula*-beds is an andesite.

#### V. THE INTRUSIVE DIABASES<sup>1</sup> AND THEIR RELATIONS TO THE STRATIFIED DEPOSITS.

The most important areas of diabase in the district examined are the Mynydd Gader mass, and the large patches which occupy so much space in the northern half of the map. The latter, as will be shown, are probably parts of a single mass.

Besides these there are a number of smaller masses or sheets, the positions of which are sufficiently indicated upon the map.

*The Dolgelly mass.*—There can be no doubt that the more southerly of the two patches of diabase which lie immediately south of Dolgelly is continuous across the Dolgelly fault with the great mass which

<sup>1</sup> [Some account of the petrological characters of these diabases will be found in Messrs. Cole and Jennings's paper (Quart. Journ. Geol. Soc. vol. xlv. 1889, p. 431). We hope, at some future date, to deal more fully with the petrology of the igneous rocks to which we have referred.]

stretches west towards Maes-angharad. This being so, the most striking feature of the whole, as shown upon the map, is the contraction of the outcrop where the streams east and west of the town have cut their valleys deep down into the igneous mass. On the high ground the width of the diabase is great, and the boundaries follow the contour-lines, reducing, however, the prominence of the curves. Where, on the other hand, the surface is lower, as in the valleys of the streams, the outcrop is narrow, and the boundaries are straight and independent of the contours. These facts indicate that at the level of the higher ground the diabase spreads out into a broad mass, the under surface of which, near its boundaries, is gently inclined; while at the level to which the valleys have been carved it forms a comparatively narrow vertical-sided dyke. The transverse section in fact is like a section of a mushroom.

Near Maes-angharad the mass narrows again; and this no doubt is partly owing to the lower level of the ground in that neighbourhood. But it may also be due in part to the Derwas fault. The downthrow of this is on its south-eastern side, and if it faults the diabase as well as the sedimentary deposits, its effect will be to bring to the surface on its north-western side a lower and therefore narrower part of the mass—to expose, in fact, the stalk instead of the head of the mushroom.

Close to Dolgelly there is a smaller patch of diabase which forms the slopes immediately above the town, and this is perhaps a part of the northern expansion of the great mass, from which, however, it has been separated by denudation. The southern boundary of this patch is a curve, the convexity of which points up the slope on which the rock occurs. The surface, therefore, which separates the igneous rock from the sedimentary deposits near it, is not vertical, but dips down hill. Moreover, the bed of the Afon Aran and the right bank of the stream above Pandy'r-odyn do not show diabase, but ash in the lower parts of their courses. These streams have cut through the diabase, and have exposed the beds below, and the diabase is therefore a sheet upon the hillside, no doubt with an irregular base.

In its mushroom-like form the great mass of diabase which stretches across the Dolgelly fault is not unlike a laccolite, but in its relations to the beds below it offers certain striking peculiarities. Its northern boundary west of the fault runs nearly parallel to the lava-band already described, so that here the mass appears to rest upon the surface of the bed below it. But along its southern boundary, whereas the surface of separation between the diabase and the stratified beds below it is shown by the map to be nearly horizontal, the stratified beds themselves dip at a fairly high angle to the south. The diabase, therefore, no longer rests upon the surface of the beds, but upon their edges. Moreover, as we have already seen, a considerable thickness of slates which should occur between the lava of the Bryn-y-gwin Wood and the ashes of Graig is invisible. These slates are probably concealed below the diabase.

On the eastern side of the fault the beds of ash, etc., which lie

between the two patches of diabase, dip to the south, while the northern diabase-patch dips towards the north. It will be noticed that the northern boundary of the southern patch follows the contour-lines, reducing, however, the sharpness of all the curves; and this shows that the base of this mass dips towards the south, following, perhaps, as on the western side of the fault, the dip of the beds below. The southern boundary, however, follows the contour-lines very closely, and the diabase near this boundary must therefore be horizontal.

The form which the mass has assumed is shown in the sections (figs. 1 & 2) on p. 520. The diabase has been intruded, with a tendency to follow the bedding up to a certain height, at which it begins to spread out horizontally. It is clear that the plane along which it has spread must have been a plane of weakness; but it is not, as in most laccolites, a bedding-plane. Thrust-planes being out of the question in this case, the most feasible explanation is that the plane was one of unconformity; that the *Lingula*-Flags and other rocks of this district were overlain unconformably by a later series, that the diabases were subsequently intruded and spread along this unconformity, and that the higher beds have since been removed by denudation. But as we have no trace of the higher beds, this explanation becomes nothing more than a suggestion.

*Mynydd Gader mass.*—The form of the Mynydd Gader diabase is similar in some respects; but here our observations are not yet completed, and we have followed only the northern boundary. If this boundary, as shown upon the map (Pl. XXIV.), be examined, it will be noticed that it is not straight but wavy, and although unfortunately the contour-lines are not drawn up to this height, it is clear that the curves are due to the form of the surface. For where a stream crosses the boundary and has cut a little valley, there the boundary recedes towards the south, while between the streams it bulges out towards the north. In the field it is found that the floors of the valleys are formed (where they are deep enough) by the lavas and other stratified beds which underlie the diabase, while the walls are formed of the diabase itself. The surface of separation between the diabase and the other beds slopes down towards the north. The Mynydd Gader diabase, therefore, along its northern boundary, forms a sheet rather than a vertical intrusion.

At the western extremity of the mass, however, these relations are not preserved. The small elliptical projection at the western end is a hill of diabase almost completely surrounded by hills of nearly equal height which are formed of stratified deposits. The diabase here forms a kind of plug or neck.

The patch of diabase which lies S.E. of Llyn Gwernan appears to be a sheet dipping towards the north, and doubtless is a continuation of the Mynydd Gader mass.

Concerning the smaller masses but little need be said: all of them show a tendency to run parallel to the strike of the sedimentary deposits, but nevertheless are probably intrusive. The small patches near Brynmawr and Bryn-rhug are very much decomposed.

Fig. 1.—Section west of the Dolgelly Fault.

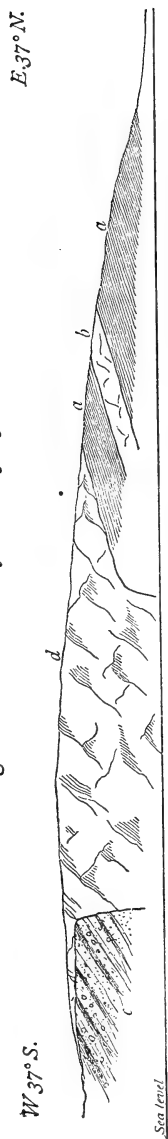
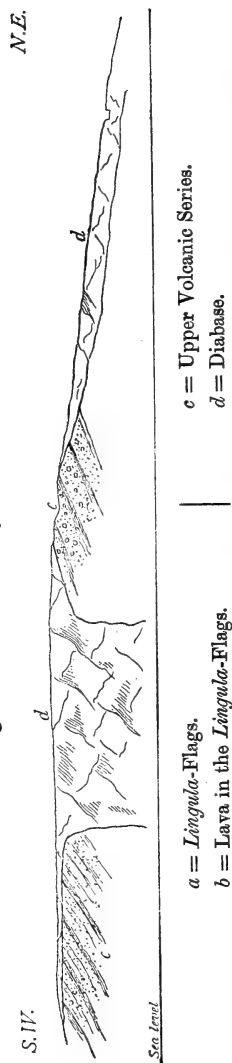


Fig. 2.—Section east of the Dolgelly Fault.



Scale (Horizontal and Vertical): 6 inches = 1 mile.



## VI. AGE OF THE INTRUSIVE ROCKS AND OF THE FAULTS.

The three chief faults shown upon the map run nearly, but not quite, parallel to one another, but they are not of precisely the same age. The Nant Ceunant fault is clearly posterior in date to the intrusion of the diabase; and, as we have seen, this is probably true of the Derwas fault also. The Dolgelly fault, on the other hand, has little influence upon the intrusive mass, although its effect upon the stratified deposits is very marked. There is, however, evidence that a small amount of movement took place along the plane of this fault after the intrusion of the diabase. The sections drawn on the two sides of the fault (figs. 1 & 2) show that the diabase spreads at different levels. North-west of the fault the lateral expansion of the diabase takes place at a height of 400 feet above the sea, and south-east of the fault at a height of 450 feet. This seems to indicate a downthrow of 50 feet on the north-western side since the intrusion of the diabase; while the downthrow of the stratified deposits (which took place before the intrusion) is on the south-eastern side of the fault.

The actual age of the Dolgelly fault is not itself determinable, but it runs parallel with the great Bala fault which, on the other side of Cader Idris, lies in the valley of Tal-y-llyn. The Bala fault is Upper Carboniferous or post-Carboniferous in date, for in its extension to the north-east it frequently faults the Carboniferous Limestone and Millstone Grit. Some geologists may be disposed to infer that the Dolgelly fault is of the same age as the Bala fault, and that the diabase is therefore post-Carboniferous in date. But this must still remain open to doubt.

If the plane along which the diabase near Dolgelly has spread in laccolitic fashion is one of unconformity, the unconformity must be newer than the Dolgelly fault, for the lateral expansion of the diabase takes place at nearly the same level on the two sides of the fault—if anything even at a higher level on the downthrow side. If, therefore, the plane is one of unconformity, either the Dolgelly fault must be pre-Carboniferous, or the unconformity must be a newer one than that at the base of the Carboniferous.

## VII. CONCLUSIONS.

In conclusion we believe we have shown that: (1) outflows of andesitic lava occurred in this region as early as the period of the Upper *Lingula*-Flags; (2) at some subsequent date intrusions of diabase took place, which show a tendency to spread out more or less horizontally along a certain plane, perhaps a plane of unconformity; (3) the diabase in some cases, as it flowed along, dragged with it great masses of the underlying rock; (4) faulting took place both before and after the intrusion of the diabase; and in one case there seems to have been movement along the plane of the fault in one direction before the intrusion, and in the opposite direction after the intrusion.

## PLATE XXIV.

Geological Sketch-map of the Neighbourhood of Dolgelly, on the scale of 3 inches to the mile.

## DISCUSSION.

The PRESIDENT said that it was interesting to find that andesitic lavas occurred in the Dolgelly Beds. Acid lavas were frequently found in the *Lingula*-Flags of North and South Wales, and beds mainly composed of volcanic ash occurred at the top of the Menevian group at St. David's and near Maentwrog. He thought that most of the diabase-intrusions in the area were of Ordovician age.

Mr. W. W. WATTS expressed the pleasure he felt that the Authors were not content with proving that the diabase-masses were of laccolitic character, though they had done that conclusively, but had gone beyond and used the existence of the laccolite to draw further conclusions as to the structure of the area. He reminded the Society that he had described laccolites of similar diabase which occurred in the Shelve district, resting unconformably on Ordovician strata and covered by Silurian rocks which were altered at the contact. It could be proved in Shropshire and Montgomeryshire that the diabases had nothing in common with Carboniferous and post-Carboniferous intrusions, and he therefore thought that the Authors' suggestion with regard to the Dolgelly masses was founded on too slender evidence.

Mr. LAKE, in reply, said that the Authors were by no means wedded to the hypothesis that the diabases were of post-Carboniferous age. The evidence derived from the faults is very uncertain. Parallel faults are not necessarily of the same age; and even in the case of a single fault, movement may take place at different periods. The absence of olivine tends rather to suggest that the intrusions may be pre-Carboniferous; and the question must still remain an open one.

31. *On the GEOLOGY of the NEIGHBOURHOOD of CARMARTHEN.* By MISS MARGARET C. CROSFIELD and Miss ETHEL G. SKEAT. (Communicated by J. E. MARR, Esq., M.A., F.R.S., Sec. G.S. Read April 15th, 1896.)

## [PLATES XXV. &amp; XXVI.]

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## I. INTRODUCTION AND BIBLIOGRAPHY.

THE area described in this communication has Carmarthen for its centre, and lies approximately within a 4-mile radius of that town, as indicated in the accompanying sketch-map (Pl. XXV.). Our object in examining this district was to trace the continuation of the complex anticline which was discovered by the late Mr. T. Roberts, about 10 miles west of Carmarthen. In the map illustrating his paper<sup>1</sup> the anticline is shown to be narrowing rapidly in the neighbourhood of Mydrim, the *Didymograptus*-beds seem to wrap round the older *Tetragraptus* series, and apparently the anticline is dying out.

An examination of the beds round Carmarthen has enabled us to establish this conclusion, and to show that in our own district we have a new anticline, the northern limb of which continues in the same direction as that of the anticline farther west, but with a core consisting of older rocks, which we correlate with the Tremadoc Slates. The southern limb of the new anticline is buried under Old Red Sandstone (which here encroaches farther north than at St. Clears), but in the northern limb we have a regularly ascending series from Tremadoc Slates to *Dicranograptus*-shales. To the east this regular succession of beds is disturbed by the presence of an extensive series of alternating grits and sandstones, with some shales, the last containing Bala fossils. The beds in question abut on those of Arenig age, but whether their appearance in this locality is due to faulting or to an unconformity we cannot at present determine, owing to the nature of the ground and the exceedingly complex character of the foldings. The clue to the relations of these beds would doubtless be discovered by an examination of the area lying to the east.

<sup>1</sup> Roberts, T., 'Notes on the Geology of the District West of Caermarthen,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 166.

The literature relating to this district is as follows:—

- DAVIDSON, T. 'British Brachiopoda,' vol. iii. pp. 232, 233, pl. xxxiii. figs. 17, 21. MEMOIRS OF THE GEOLOGICAL SURVEY, vol. i. (1846) p. 25 & vol. ii. (1848) pt. i. pp. 262 *et seqq.*
- MURCHISON, R. I. 'The Silurian System' (1839), pt. ii. pp. 355, 358, 361, 664 & 720, pl. xxv. figs. 3 *a*, 3 *b* & pl. xxxiv. fig. 9.
- . 'Siluria,' 5th ed. (1872) pp. 55–58.
- SALTER, J. W. 'A Monograph of the British Trilobites' (1864), p. 173, pl. xviii. fig. 11 & pl. xxv. fig. 4.
- SYMONDS, W. S. 'Records of the Rocks' (1872), pp. 99, 100, 125.

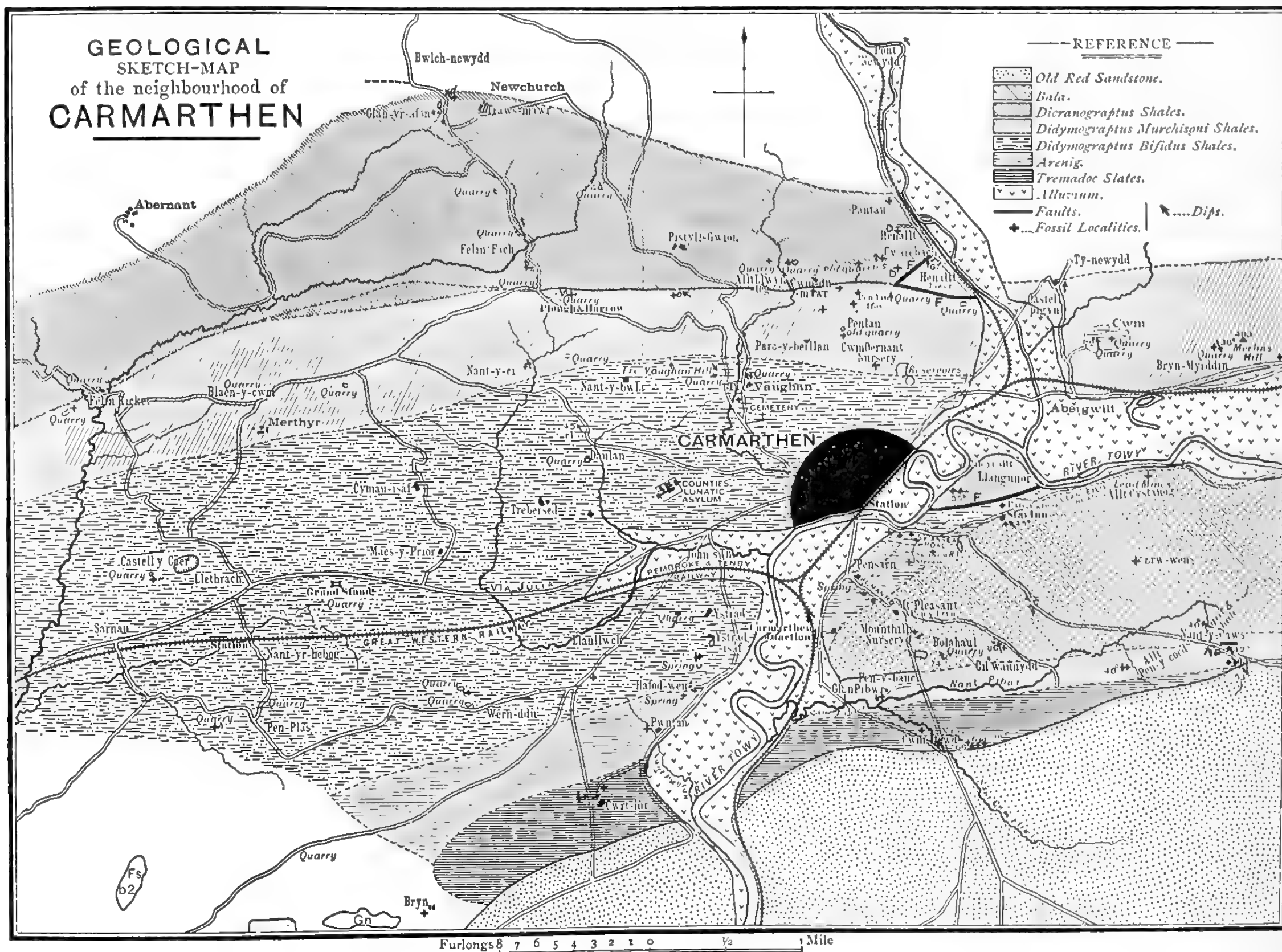
The district was geologically surveyed by Sir H. De la Beche and Mr. W. E. Logan in 1845, with additional Silurian lines by Mr. W. T. Aveline in 1855–56, and is shown on Sheet 41.

## II. PHYSICAL STRUCTURE.

The physical structure of the country is sufficiently marked to demand a slight description. The most striking features are the isolated hills with their steep sides, abrupt squarish outlines, and flat tops sloping westward, as, for example, Llangunnor and Trevaughan Hills, and Bryn Merthyn. These hills are part of the system of roughly parallel ridges which cross the country from north-east to south-west. The practically uniform level of the hill-tops, which range from 400 to 500 feet in height, and the presence of the common westerly slope suggest that we have here an ancient plain of marine denudation. The axes of the hills are formed of bedded grits, sandstones, or slates in a vertical position, while the valleys consist of the softer shales. This structure is primarily due to the earth-movements to which this district, like the rest of South Wales, has been subjected, but the processes of denudation have emphasized it and laid it bare. The streams flowing east and west have worn away the softer shales, forming valleys with gently sloping sides; the dip-valleys, on the other hand, are strikingly deep and narrow, and the streams have cut out steep and rocky gorges. The river Towy enters the district from the east, but makes a sharp southward bend near the town, where it is joined by its tributary the Gwili; the united streams then take a remarkably sinuous course, and have covered the broad level valley with a thick deposit of alluvium. It seems probable that the river-bed marks a line of considerable geological disturbance. The district is bounded on the south by the long low range of Old Red Sandstone hills, and the undulating slopes of these present a marked contrast to the often abrupt outlines of the hills formed of the older rocks. The earth-movements which have affected this district are so complicated that it would be useless to attempt to give any exact idea of their effects within the limits of this paper. They have resulted in the formation of innumerable folds and faults, the latter of which are most noticeable in the north just outside our district. The distribution of the folds makes it possible roughly to distinguish two great periods of earth-movement. The first period gave rise to an immense number of small anticlines and synclines, the axes of which run north and south. In consequence of this folding the beds











frequently crop out along north-and-south lines for a short distance, as is well seen in Mr. Roberts's district to the west. After this universal crumpling of the crust had taken place a second period of folding on a still grander scale set in. This was evidently part of that great movement which produced the Condrozian ridge, and all the beds of this part of Wales were affected by it. In the end a great series of huge anticlines and synclines were formed with their axes running east and west, so that the second movement was at right angles to the first. A single limb of one of these complex anticlines forms the subject of the present paper. The uniform direction (N. to N.W.) of the cleavage throughout the district shows that it was produced either simultaneously with this last folding or at a later period.

### III. THE SUCCESSION AND DETAILED DESCRIPTION OF THE BEDS.

#### 1. Tremadoc Slates.

About  $2\frac{1}{2}$  miles south-west of Carmarthen, exposed in the banks of the Nant-y-Glasdwr, are fine-grained blue-grey shales, which weather a rich yellow or brown, and are often iridescent. Intercalated with the shales are occasional bands of micaceous sandstones. The beds dip  $68^\circ$  due south, and pass immediately under the Old Red Sandstone. They have yielded *Ogygia marginata*, n. sp., *Parabolinella*, n. sp., *Peltura punctata*, n. sp., *Orthis*, and *Orthoceras*. *Peltura punctata* occurs very abundantly, *Ogygia marginata* much less frequently, and only one specimen of *Parabolinella* was obtained.

#### *Confirmatory Sections.*

A little west of the Nant-y-Glasdwr, in the Nant Pibwr at Cwm Ffrwd, the shales are more gritty, and assume the character of mudstones. Alternating with them are some hard grey grit-bands. The junction with the Old Red Sandstone is seen in the bed of the stream, and near it the shales are considerably disturbed, the dip varying repeatedly in the space of a few yards; elsewhere the dip is south. We found here *Ogygia marginata*, *Peltura punctata*, *Orthoceras sericeum*, Salt., and *Modiolopsis*. The *Ogygia* occurs much more plentifully here than in the Nant-y-Glasdwr, but no perfect specimens were obtained. On the western side of the River Towy near Cwrt Hir Farm, in a hole by the roadside, we found fragments of *Erinnys*, sp., *Peltura punctata*, and *Orthis*; and a little east of this, in Cwrt Hir carriage-drive, where there is an alternating series of coarse grits and shales, we found in the shales *Ogygia marginata* and a species of *Orthis*.

#### 2. Arenig Beds.

A typical section of these beds is seen just below Glan Pibwr Cottage, in the narrow lane which leads down to the stream. They consist of fine-grained, dark, bluish-grey mudstones, finely bedded, and weathering in iridescent shades of brown and red. The rock

greatly resembles the Tremadoc Slates, but, on the whole, is harder, and not interstratified with grits or sandstones. The shales in the lane dip south, and thus pass under the older Tremadoc Beds. We find this inversion of the normal succession in all the strata on the southern side of what we may term the Mount Pleasant and Ystrad ridge. The fossils obtained here were mainly trilobites, but a few specimens of *Phyllograptus*, sp., were also found. The list is as follows:—*Ampyx*, sp., *Ogygia marginata*, *Ctenodonta*, *Phyllograptus*, sp., cf. *angustifolius*, Hall. At Pen-y-banc, about  $\frac{1}{2}$  mile eastward, the same species of *Ogygia* and a *Lingula* were obtained.

### Confirmatory Sections.

The small stream above Pwntan House, west of the river Towy, has cut its way through similar mudstones of a rather lighter colour. In this rock the bedding-planes are tolerably far apart, and the intervening rock breaks with difficulty. The fossils are abundant and well preserved, but consist entirely of *Ogygia marginata* and of a few specimens of *Ctenodonta*. East of the Towy similar mudstones may be seen in the brook which passes under the road close to Carmarthen Junction, but only a few distorted portions of *Ogygia marginata* were obtained.

At Allt Pen-y-coed, 2 miles nearly due east of Carmarthen Junction, the mudstones are exposed in a fine deep gorge; the beds are not very fossiliferous, but yielded a head and tail of *Ogygia*, sp., cf. *Selwynii*, Salt.

In the banks of the Nant-y-Caws, on the same strike, is a great thickness of shales lithologically similar to those of Glan Pibwr, but containing, both in the upper and lower parts of the gorge, bands of grit and some conglomerates. As the dip varies from  $35^{\circ}$  N., not far from the bridge in the lower part, to  $55^{\circ}$  S.  $30^{\circ}$  E. at the waterfall, where the junction with the Old Red Sandstone occurs, we have probably here a small subsidiary anticline. These shales are very unfossiliferous, and only yielded *Orthoceras sericeum* and *Conularia*. We have placed these beds provisionally with the Arenig Series, but whether they do not belong rather to the Tremadoc Slates is open to question.

Lying to the north of the beds which we have just described are others of similar lithological and palæontological characters, differing only in the fact that they contain in addition *Calymene parvifrons*, var. *Murchisoni*, Salt.

The chief localities where the beds containing *Calymene* crop out are (i.) the *Roman Road*.—This exposure extends along both sides of the deep lane of this name in the Pensarn district of Carmarthen. The beds are shaly throughout, but vary in character in different parts of the road. In the hard, rather flaggy beds, about halfway up the lane many fossils were found in a very fragmentary condition, this being partly due to the fact that the bedding is almost at right angles to the cleavage. Higher up the road the shales are hopeless for purposes of search, being crushed and weathered to such an extent that they break always into long billet-shaped frag-

ments, without any clear face. This appearance is very characteristic of the beds whenever they occur in a weathered condition. The fossils obtained were *Bellerophon*, *Ampyx*, *Calymene parvifrons*?, Salt., *C. parvifrons*, var. *Murchisoni*, Salt., *C. Tristani*?, Brongn., distorted fragments of Asaphid trilobites.

(ii.) *Swansea Road Streams*.—From the sloping ground which bounds the southern side of Swansea Road two small streams flow northwards to join the Towy. In the lower part of one of these streams we have the *D. bifidus*-shales, but higher up and apparently dipping under these are mudstones which closely resemble those of Nant Pwntan in colour and hardness. We found here *Calymene parvifrons*, var. *Murchisoni*, Salt., *Ogygia marginata*, *Orthoceras*, and a small *Asaphus*, sp., Salter; an exposure in the second streamlet yielded a *Calymene*.

In the banks of the steep lane leading to Cilwaunydd Farm were weathered shales containing *Bellerophon*, *Calymene parvifrons*, var. *Murchisoni*, Salt., and *Ogygia marginata*.

Totally distinct from these mudstones, and without a fossil in common with them, are the shales of Hafod-wen spring on the western side of the River Towy. These beds contain a graptolite fauna of Arenig age, but lithologically they resemble the Llanvirn Beds to be next described. We obtained here *Didymograptus nitidus*, Hall, *D. ? constrictus*, Hall, *D. ? Murchisoni*, Beck, *Dictyograptus*, sp., *Æglina binodosa*, and ostracoda.

### 3. *Didymograptus bifidus*-beds (Llanvirn).

These beds consist in some parts of shales alone, in others we have alternating bands of light-grey shales and grey grits, weathering yellow. The grits, which generally are jointed, and often veined with quartz, vary in thickness from a few inches to several feet; the shales occur in bands of 6 inches or less. The alternating grit- and shale-bands form a well-marked ridge of hills extending for a considerable distance along the southern side of the Pembroke and Tenby Railway. The beds are almost vertical, but have a general northerly dip on the northern side. Five quarries are cut out on the hillsides, those of Ystrad, Llanllwch, Wernddu, Nant-yr-hebog, and Pen Plâs. In the last-named a thicker series of shales is seen just outside the quarry, dipping over the grit-beds, and here *Phacops llanvirnensis*, Hicks, was found. At Wernddu we obtained *Didymograptus indentus*, Hall; near Llanllwch and in Ystrad quarry *D. bifidus*, Hall. North and south of this ridge the beds consist of shales only; these are of a light-grey colour, fairly soft and well cleaved. South of the ridge, at Ystrad Isaf and Hafod-wen lane, we found *Didymograptus bifidus*, Hall, *D. indentus*, Hall, and *Diplograptus dentatus*, Brongn. North of the railway in Trebersed stream a crushed graptolite of the *D. patulus*-group and a fragment of an eye of *Æglina* were obtained; at Castell-y-gaer a portion of a *Didymograptus*, sp., and of an eye of *Æglina*; farther east, near Trevaughan Hill, we found *Didymograptus indentus*, Hall, and *Diplograptus dentatus*, Brongn.

The beds also occur on the eastern side of the Towy, but the grit-bands do not form here such a prominent feature as on the western side. In the small quarry near the beginning of the Swansea Road, after crossing the river near Carmarthen, the beds are bent completely over, and form a small subsidiary anticline, the axis of which is at right angles to the general strike of the series in the Ystrad ridge; lithologically, the beds are exactly similar to those already described. The shales which overlie the grits may be seen in the road-cutting for about  $\frac{1}{8}$  mile; they are dark grey or nearly black, and much contorted. In the quarry and along the road we found *Climacograptus cælatus*, Lapw., *C. confertus*, Lapw., *Dendrograptus*, sp., cf. *flexuosus*, Hall, *Didymograptus bifidus*, Hall, *D. indentus*, Hall, *D. Murchisoni*, Beck, *Lingula*, and *Siphonotreta micula*. In the small stream above the road we found *Didymograptus bifidus*, Hall, and *Ampyx*, sp.

At Cwarebach and Lower Henalt we have apparently an isolated patch of beds of the same age faulted against *Dicranograptus*-shales. The slates are fine-grained, bluish grey, striped with a lighter grey, and well cleaved; they yielded *Dictyograptus*, sp., vel *Callograptus*, sp., cf. *Salteri*, Hall, and *Climacograptus*, sp., cf. *confertus*, Lapw.

A little south of Cwm Farm, near the town of Abergwili, are several small quarries containing hard grey shales, gritty shales, and striped flags. Here *Acidaspis Buchii*, Barr.,<sup>1</sup> and *Ampyx*, sp., were obtained.

TABLE OF FOSSILS FROM THE *Didymograptus bifidus*-SHALES.

	Hafof-wen Lane.	Ystrad Isaf.	Ystrad Quarry.	Llanllwch.	Wernddu.	Pen Plas.	Castell-y-gaer.	Trebersed.	Trevaughan Hill.	Cwm.	Swansea Road and Lower stream.
<i>Didymograptus bifidus</i> , Hall .....	..	*	*	*							*
— <i>indentus</i> , Hall .....	..	*			*						*
— <i>Murchisoni</i> , Beck .....	..										*
— <i>patulus</i> group .....	..							*			..
<i>Diplograptus dentatus</i> , Brongn. ....	*								*		..
<i>Climacograptus confertus</i> , Lapw. ....	..										*
— <i>cælatus</i> , Lapw. ....	..										*
<i>Dendrograptus</i> , sp., cf. <i>flexuosus</i> , Hall ...	..										*
<i>Ampyx</i> , sp. ....	..									*	*
<i>Æglina</i> , sp. ....	..						*	*			*
<i>Acidaspis Buchii</i> , Barr. ....	..									*	..
<i>Phacops llanvirnensis</i> , Hicks .....	..				*						..
<i>Lingula</i> .....	..										*
<i>Siphonotreta micula</i> .....	..										*

<sup>1</sup> Kindly named by Mr. Philip Lake, F.G.S.

#### 4. *Didymograptus Murchisoni*-shales.

The outcrop of this series serves as a datum-line throughout the district, owing to the fact that the fossils are characteristic and abundant. The beds sweep across the country in a straight line from Felin-wen on the east to beyond Nant-y-ci on the west. From this point westward the outcrop takes a southerly bend, owing to the closing in of the anticline, and exposures occur south of Melin Ricket as described by the late Mr. Roberts. The general dip of the beds is magnetic north, at a greater or lesser angle with that of the cleavage. No actual junction with the higher beds is seen except in Pistyll-y-gwion quarry, where a yellow sandy series overlies the shales. The sporadic appearance of this sandstone, and the fact that we have here the higher beds of the *Didymograptus Murchisoni*-zone, render it admissible to suppose that the sandy rock is a local development of Llandeilo Limestone, otherwise absent throughout the district. Just north of the Plough and Harrow Inn higher beds also occur. No certain boundary-line can at present be drawn between these beds and the underlying *bifidus*-shales, as fossils are so exceedingly rare in the upper part of the latter.

An extensive exposure of the *Didymograptus Murchisoni*-beds is seen in the large quarry behind the Plough and Harrow Inn. They consist of dark-grey shales, with lighter stripes of more sandy material at close intervals. These stripes show the direction of the bedding, which is at an angle with that of the cleavage. The beds contained *Didymograptus Murchisoni*, Beck, and *Siphonotreta micula*.

#### *Confirmatory Sections.*

These beds are so well known elsewhere that we need only mention the chief exposures. Proceeding from the west eastward, we have:—

(i) The small quarry marked on the 6-inch map as Nant-y-ci sandpit; the purplish slates contained *Didymograptus Murchisoni*, Beck, and *Climacograptus confertus*, Lapw.

(ii) Pistyll-y-gwion quarry must be specially mentioned, on account of the overlying sandy series. The sandstone was somewhat coarse-grained and very ferruginous, and in it we found *Orthis testudinaria*, Dalman. The shales yielded *Didymograptus Murchisoni*, Beck, *Climacograptus confertus*, Lapw., *Lingula*, and *Asaphus tyrannus*, Murch.

(iii) In Penlan old quarry and on Penlanffôs Hill the same shales are seen. In the old filled-up quarries on the hill some specimens of *Diplograptus foliaceus*, Murch., were also found, owing to the fact that we have here a junction with the higher beds. At Cwm-oernant Nurseries specimens of *Didymograptus Murchisoni*, Beck, were obtained.

In the Abergwili district to the north-east of the map we have three principal exposures. At Castell-pigyn are dark finely-splitting slates alternating with harder flaggy beds. At Felin-wen the

shales are lighter in colour, brittle, and extremely fissile: here the fossils are most plentiful. We obtained *Didymograptus Murchisoni*, Beck, *Orthis testudinaria*, Dalman, *Lingula*, and *Orthoceras*. Near the top of Merlin's Hill is a small quarry of the same shales, which are much weathered, and the fossils are not found on the cleavage-faces.

### 5. Llandeilo Limestone.

There is no Llandeilo Limestone in the district, but, as already suggested, this formation may be represented by the gritty and sandy flags, which are found at the northern limit of the *Didymograptus Murchisoni*-shales. In these beds we found *Asaphus tyrannus*, Murch., and *Orthis striatula*, Dalman; but we have not attempted to separate them from the lower ones. The limestone that is used for agricultural purposes is brought from a distance, and is mainly of Carboniferous age.

### 6. *Dicranograptus*-shales.

These beds are dark blue or black in colour, soft and well cleaved. They are seen to dip over the *Didymograptus Murchisoni*-shales, but the actual junction with the lower beds has not been determined. Fossils are rare except in occasional bands, and can be obtained only in a fragmentary condition, as the rocks are generally cleaved at an angle with the bedding. The shales are best seen on the Cardigan Road, and are exposed for about  $\frac{1}{2}$  mile from Cwarebach on the south to near Pantau on the north, where they dip under a great series of hard, unfossiliferous, silvery-grey flags. The fossils obtained from this exposure were *Climacograptus bicornis*, Hall, and *Diplograptus*, sp.

### *Confirmatory Sections.*

The beds may be traced in several sections westward. At Cwm-du-Mawr and Allt Llyn Teg the beds are black and sometimes very carbonaceous. They yielded *Diplograptus foliaceus*, Murch., and *D. dentatus*, Brongn. At Felin Fach quarry and in the lane near the Plough and Harrow Inn, where the rock closely resembles that of Cwm-du-Mawr, the same fossils occur. Near Glan-yr-Afon in the same road, but a mile to the north, *Diplograptus foliaceus*, Murch., was found. Between these last-named exposures we have a series of unfossiliferous, soft, pale-grey satiny shales cropping out, which is considerably folded, and of the age of which we are ignorant.

In a quarry near Tan-yr-allt Farm, on the western slope of Llangunnor Hill, are pale-grey slates, weathering brown, interstratified with hard micaceous striped slates of a gritty texture. The beds are very barren, but yielded one specimen of *Dicranograptus*, sp., cf. *ramosus*, Hall.

## 7. Bala Beds.

Partly surrounded by shales of Arenig age is a great series of mudstones, grits, sandy flags, sandstones, and conglomerates. These beds extend from near Mount Pleasant, the residence of Sir Lewis Morris, for more than a mile in an easterly direction, and probably farther. They are bounded on the north by the Arenig Beds of the Roman Road and by the River Towy. On the south they rest on the Arenig Beds of Glan Pibwr and Cilwauntydd. In the centre of the series the beds are perpendicular, as is well seen in the flagstones and pebble-beds of Bolahaul Quarry, and in the alternating grits and shales in the quarry opposite Mount Pleasant Nurseries. Fossils of Bala age have been found at Pensarn, the Star Inn, Allt Cystanog, and Erw-wen. Pensarn is classical ground, for in the dark-blue brittle mudstones which occur near the northern end of the deep lane called the Roman Road, Lady Murchison<sup>1</sup> found *Stygina* [*Ogygia*] *Murchisonæ*, Murch., which was figured with other fossils from the same locality by Sir R. I. Murchison. This appears to be a small isolated patch of Bala Beds, as it occurs between the Arenig Beds of the upper part of the lane and the Llanvirn Beds to the north. Close to the spot marked 'Spring' on the 25-inch Ordnance map we obtained ?*Homalonotus*, *Stygina Murchisonæ*, Murch., *Orthis alata*, Sow., and *Bellerophon*.

*Confirmatory Sections.*

In a lane behind the Star Inn, on the Llandeilo Road, the beds are more flaggy in character; here we obtained *Lingula tenuigranulata*, *L. lævis*, *Orthis alata*, Sow., and *Nucula lævis*. These flags, which lie on the northern slope of the Mount Pleasant ridge, may be traced for a short distance up the hill, and are seen again at Erw-wen,  $\frac{3}{4}$  mile south-east on the southern slope of the hill. Here we found *Orthis alata*, Sow., *O. calligramma*, Dalm., *O. flabellulum*, Sow., *Lingula*, sp., *Bellerophon*, and *Nucula*.

At Allt Cystanog mudstones lithologically similar to those of Pensarn have been turned out of the new lead-mine. Here we collected *Lingula tenuigranulata*, *Orthis alata*, and *O. flabellulum*.

In a quarry opposite Mount Pleasant Nurseries we found a few fragments of *Holopella*.

## IV. COMPARISON WITH THE DEPOSITS OF OTHER AREAS.

## 1. Tremadoc Slates.

It is unfortunate that we have not found in these beds a single fossil which is characteristic of the Tremadoc Slates in other parts of Britain. The commonest trilobite that occurs is a new species of *Peltura*, Milne-Edwards; but we have also two other Cambrian forms: a *Parabolinella* closely resembling *P. rugosa*, Brög., which is

<sup>1</sup> 'Silurian System,' pt. ii. pp. 358 & 664, & pl. xxv. figs. 3 a, 3 b.

found in the *Ceratopyge*-Limestone, stage  $3a^{\gamma}$ , and *Erinnys*, sp. Associated with these typical Cambrian genera is the Ordovician genus *Ogygia*, represented by a large new species, which occurs sparingly in our lower beds, becomes more common as we pass higher, and finally is very abundant in beds of Arenig age.

This mixture of Cambrian and Ordovician forms indicates the position of these beds in the stratigraphical succession, and enables us to correlate them in a general way with the Tremadoc Slates of North Wales and with the Shineton Shales of Shropshire.

In the attempt to fix the horizon of these beds yet more definitely we have compared our fossils with those found in Stages 2 and 3 in Scandinavia<sup>1</sup>; and we observe that both the subgenera *Peltura* and *Cyclognathus* properly belong to Stage 2 (*Olenus*-Etage), although one species of *Cyclognathus* (to which subgenus our form, strictly speaking, belongs) is found at the very base of Stage 3 (*Asaphus*-Etage).

As *Peltura punctata*, sp. n., is by far the commonest fossil in our beds, we are inclined to consider that here we have the equivalents of the lower part of Stage  $3a$ , which Brögger<sup>2</sup> has correlated with the Shineton Shales. On the other hand, the presence of *Orthoceras* throughout our beds would suggest that we have the representatives of  $3a^{\beta}$  or  $3a^{\gamma}$ , for this genus is not recorded by Brögger as occurring below the upper part of  $3a^{\beta}$ . Our species of *Parabolinella* closely resembles *P. rugosa*, Brög., which is confined to  $3a^{\gamma}$ .

It thus seems unwise, if not impossible, to define the position of our beds more closely than by saying that they are of the age of the Tremadoc Slates, and the equivalents of part or of the whole of Stage  $3a$ ; but as the shales are very rich in fossils, we hope that additional species will ere long be found to throw further light on the question.

## 2. Arenig Beds.

The presence of *Phyllograptus*, sp., cf. *angustifolius*, Hall, at Glan Pibwr, and of *Calymene parvifrons*, var. *Murchisoni*, Salt., in the Roman Road, and Swansea Road upper stream, both associated with *Ogygia marginata*, sp. n., which has come up from the Tremadoc Beds, indicate the Arenig age of these mudstones; and that the graptolitic shales of Hafod-wen are of the same period is shown by the presence together of such forms as *Didymograptus nitidus*, Hall, *Dictyograptus*, sp., and *Æglina binodosa*. These beds are the equivalents of the *Phyllograptus*-shales of Wales and Scotland, of part of the Skiddaw Slates, of the Lower Graptolite or *Phyllograptus*-shales of Norway and Sweden, of the Point Levis Beds, and of the St. Anne Zone of Canada.

<sup>1</sup> Brögger, 'Die silurischen Etagen 2 und 3 im Kristianiagebiete,' 1882.

<sup>2</sup> *Ibid.*



*Lower Arenig.*

*Phyllograptus angustifolius*, Hall, is found in Britain, both in the Lower and Upper Zones of the Arenig, and has a wide range in Scandinavia, so that its occurrence at Glan Pibwr is not sufficient to determine the horizon of the beds. The absence of *Calymene parvifrons*, var. *Murchisoni*, Salt., at Glan Pibwr and Nant Pwntan, and the very great abundance of *Ogygia marginata*, which is also common in the Tremadoc Beds of Cwm Ffrwd, suggest that possibly these beds are of Lower Arenig age. The evidence which we obtain from their position in the field supports this opinion. The Glan Pibwr Beds are only separated from the soft Tremadoc shales of Cwm Ffrwd by a continuation of low-lying ground, presumably of the same age; and the Nant Pwntan exposure lies between the Tremadoc Slates of Cwrt Hir and the graptolite-shales of Hafod-wen, in the latter of which are fossils from the *Tetragraptus*-zone. It is impossible to compare these beds with those of other areas until more fossils are obtained.

*Upper Arenig.*

In the shales of Hafod-wen occur *Didymograptus nitidus*, Hall, *D. constrictus*, Hall, *Dictyograptus*, sp., and *Ægina binodosa*, which determine the Upper Arenig age of these beds. Although we have not found the characteristic *Tetragraptus*, yet the similarity of our fossils to those obtained by the late Mr. T. Roberts, at Talfan etc., suggests that at Hafod-wen we have the same beds reappearing. The shales may be correlated also with the Upper (formerly Middle) Arenig of St. David's, and with part of the *Tetragraptus*-zone of the Skiddaw Slates described by Mr. J. E. Marr.<sup>1</sup>

We have not been able to determine whether the mudstones of the Roman Road and Swansea Road stream underlie the Hafod-wen shales, or whether they are on the same horizon but of a totally different facies. The association of *Calymene parvifrons*, Salt. (a typical Arenig fossil of North Wales, where it is found along with *Ogygia Selwynii*), with *Ogygia marginata*, shows that we cannot class these beds with the Llanvirn Group. We find also *Calymene parvifrons*, var. *Murchisoni*, Salt.; as this fossil is recorded by Dr. Hicks from Porth Hayog, Ramsey Island, together with *Didymograptus nanus*, *D. bifidus*, *D. indentus*, and *D. patulus*, its occurrence in the Carmarthen beds points to the probability that they are near the upper limit of the series.

**3. *Didymograptus bifidus*-shales (Llanvirn).**

These beds contain *Phacops llanvirnensis*, Hicks, *Didymograptus bifidus*, Hall, and other fossils common in the Llanvirn (=Lower Llanvirn of Dr. Hicks) of St. David's, with which beds they are exactly comparable. The occurrence of *Acidaspis Buchii*, Barr., connects the Carmarthen beds directly with Stage D<sup>d</sup> of Bohemia,

<sup>1</sup> Marr, 'Notes on the Skiddaw Slates,' Geol. Mag. 1894, p. 122.

and also with the slates of Angers, in both of which this fossil is found abundantly in conjunction with *Placoparia*. These forms are characteristic of the well-known Llanvirn fauna, and fix the position of the shales beyond question.

#### 4. *Didymograptus Murchisoni*-shales.

These are too well known to require much notice here; they evidently correspond to Hicks's Lower Llandeilo or Upper Llanvirn beds of Abereddy Bay, and to part of Messrs. Marr and Roberts's *Didymograptus*-shales of Haverfordwest. Very few fossils were found except the characteristic *Didymograptus Murchisoni*, Beck, and this was abundant. These beds everywhere succeed the *Didymograptus bifidus*-shales which constitute the true Llanvirn (Lower Llanvirn of Dr. Hicks) horizon. We see the same relations of the beds in Scania. Tullberg's division E, Middle Graptolite Shales, has at the base a zone O = *D. Murchisoni*-zone.

E (O) is divided into.  $\left. \begin{array}{l} \alpha \\ \beta \end{array} \right\}$  with *Didymograptus Murchisoni*.

$\gamma$ . Corresponds to part of our *Didymograptus bifidus*-zone.

#### 5. *Dicranograptus*-shales.

These beds regularly succeed the *Didymograptus Murchisoni*-shales: near the base we have a zone containing *Diplograptus foliaceus*, Murch., and *D. dentatus*, Brongn.; in a higher band *Climacograptus bicornis*, Hall, was found. *Dicranograptus ramosus*, Hall, occurs alone, so that the relationships of the sub-zones to one another cannot yet be made out. *Orthis argentea*, which is characteristic of the upper bands of the *Dicranograptus*-shales at Haverfordwest (Quart. Journ. Geol. Soc. vol. xli. 1885, p. 478), has not been found in the Carmarthen district. We have no difficulty in correlating these beds with the Glenkiln Series described by Prof. Lapworth, and placed by him at the very top of the Llandeilo Series. Not only are the chief fossils identical, but their distribution is also strikingly similar, as is shown by the following table:—

GLENKILN BEDS.		<i>Dicranograptus</i> -SHALES.
<i>Dicranograptus ramosus</i> , Hall.	R.	R.
<i>Climacograptus bicornis</i> , Hall.	C.	C.
<i>Diplograptus dentatus</i> , Brongn.	R.	R.
„ <i>foliaceus</i> , Murch.	C.	C.

The same beds occur in Abereddy Bay, at Haverfordwest, Builth, Conway, in the Lake District, in County Down, and also in Sweden.

#### 6. Bala Beds.

The age of the fossiliferous part of the Mount Pleasant series is determined by the presence of *Lingula tenuigranulata*, which is found elsewhere in rocks of Bala age, and is not known to occur on

a lower horizon. Further evidence for the Bala age of these beds is the occurrence of *Stygina Murchisonæ*, Murch. For many years Pensarn was the only known locality for this fossil, but it has been found by Messrs. Nicholson and Marr in the Drygill Shales. A large assemblage of fossils from the same district has been examined by Miss Elles and Miss Wood, and they have recently<sup>1</sup> shown that these beds are of Bala age.

The grits, sandstones, and conglomerates have only yielded a solitary fossil, *Holopella*, so that we reserve our opinion on the age of this part of the series until we can examine them more fully. In this connexion it is, however, interesting to note that Sir R. I. Murchison considered the 'schists,' grits, and sandstones as of one and the same age; but he compared them with the slates of Angers, and placed them at the very base of the Llandeilo.

#### V. DESCRIPTION OF SOME NEW SPECIES OF TRILOBITES.

##### Genus *Peltura*, Milne-Edwards.

*Peltura punctata*, sp. nov. (Pl. XXVI. figs. 1-10.)

*General form*.—Long oval, slightly narrowing towards the posterior end. Very gently convex. Trilobation distinct.

*Head*.—Rather more than a semicircle, wider than long; length about  $\frac{3}{8}$  that of the whole body, surrounded by a narrow raised border, which widens slightly in front of the glabella, where it is ornamented by a row of about twenty puncta placed in a groove. Glabella gently convex, parallel-sided, longer than broad, with two pairs of distinct lateral furrows curving slightly backward, a third anterior pair being sometimes very faintly visible. The second and third pairs of furrows occupy rather more than  $\frac{1}{3}$  of the width of the glabella. Axal furrows well marked. The neck-furrow cuts off a wide segment, and extends right across the posterior end of the glabella. The neck-segment is crossed on each side by a sloping furrow, which cuts off a triangular piece as in *Peltura scarabæoides*. In the centre of the segment is a small tubercle. The fixed cheeks are large, triangular, and gently convex; the neck-furrow on the cheeks is very near the posterior margin, this furrow is continued round the genal angle and a little way up the side. Free cheeks narrow, generally absent. Genal angles rounded. Eyes small, placed very far forward, just below the punctate border. Palpebral lobe prominent. Ocular ridge distinct on some specimens, but not always well marked off.

*Thorax* with twelve segments; nearly half as long again as the head. Axis wider than the greatest width of the pleura, gently tapering towards the posterior end. In the centre of some of the segments a small tubercle is visible. Pleura nearly straight, sharply elevated as far as the fulcrum, which is placed  $\frac{1}{4}$  or less of the

<sup>1</sup> Miss G. L. Elles and Miss E. M. R. Wood 'On the Drygill Shales,' Geol. Mag. 1895, p. 246.

distance out, and then gently decurved. Obliquely grooved throughout their length; ends rounded anteriorly, but with exceedingly short sharp points curving backward, closely resembling those of *Cyclognathus micropygus*.

*Pygidium* very small, much broader than long. Axis wide, marked with three rings, not continuous across. Terminal portion small. Side lobes with two or three faint furrows. Margin entire? A single rolled-up specimen was found at Nant-y-Glasdwr.

We recognize this species as belonging to the genus *Peltura*, Milne-Edw., from the forward position of the eyes, their small size, the rounded genal angles, and the pointed pleura; but we refrain from placing it in any of the recognized subgenera. We consider it closely related to the species of the subgenus *Peltura* (sensu stricto), Ang., and yet more so to those of *Cyclognathus*, Linrs. This latter subgenus is, however, too ill defined to be of practical use as it stands. The chief distinctions between *Cyclognathus*, Linrs., and *Peltura* (sensu stricto), Ang., are that in *Cyclognathus* the glabella-furrows are indistinct or absent, and the pygidium is generally small, with an entire margin; in *Peltura*, on the other hand, the glabella-furrows are distinct and the margin toothed. *Cyclognathus transiens*, Brög., however, bridges over the gap between the two subgenera by having teeth on the margin of the tail; further, in *Cyclognathus costatus*, var. *minor*, Brög., the glabella-furrows are as distinct as in *Peltura scarabæoides*.

Brögger also shows that Linnarsson's distinction, based on the small size of the tail in *Cyclognathus*, does not hold. For this reason we refer this new form simply to the genus *Peltura*, Milne-Edw.

It differs from *Peltura scarabæoides*, Wahlenb., in the shape of the glabella, which is parallel-sided, not parabolic, and in the shape of the fixed cheeks. These in *P. scarabæoides* taper more towards the anterior end, and do not extend so far forward. The new form has a row of puncta in the groove between the anterior border and the glabella, the pleura do not taper towards the ends, and the points of these are much shorter than in *P. scarabæoides*. The pygidium is also here very much smaller, and the margin appears to be entire, not toothed. The free cheek is very much narrower than in any species of *Peltura*. The form of the pleura and fixed cheeks, the punctate border and entire margin of the tail also distinguish this form from *Peltura bidentata*, Brög., and the latter feature from *P. planicauda*, Brög. In the shape of the pleura it approaches very nearly to *Cyclognathus micropygus*, Linrs.; the pygidium seems to be intermediate between those of *Cyclognathus micropygus*, Linrs., and *C. costatus*, Brög.; but the head differs widely from either of these.

*Localities and Horizon*: Nant-y-Glasdwr, Cwm Ffrwd, Cwrt Hir, Carmarthen. Tremadoc Slates.

Measurements of *Peltura punctata*, sp. nov.

(These measurements are of a medium-sized but almost perfect specimen.)

	Inch.
Total length .....	·94
Length of head.....	·34
Length of thorax .....	·52
Length of tail .....	·08
Width of head .....	·40
Greatest width of glabella .....	·22
Width of glabella at base .....	·20
Greatest width of body .....	·44
"    "    pleura .....	·14
"    "    axis .....	·20
Distance of fulcrum from axis .....	·04

Genus *Olenus*, Dal. Subgenus *Parabolinella*, Brög.*Parabolinella*, sp. nov. (Pl. XXVI. figs. 11 & 12.)

This trilobite presents sufficient differences from the *P. rugosa* described by Brögger to admit of its being considered a new species or variety. As we have, however, only one specimen, and that is somewhat imperfect, we prefer to withhold a complete determination until better specimens are found. The present example consists of the glabella and fixed cheeks only; it is a good deal larger than Brögger's figured specimen of *P. rugosa*, being ·46 inch long and ·5 inch wide. As in *P. rugosa*, the glabella narrows slightly forwards, but it is somewhat wider in proportion to the length than is the case in that form. A very small portion of the anterior margin is seen on the right side. Here, too, there are three principal pairs of glabella-furrows, of which each anterior furrow is shallower in the middle; the two posterior pairs being bent sharply backward, and also branched. The branching is, however, not quite identical with that which occurs in the furrows of *P. rugosa*, as the second branch of the posterior furrow deepens more towards the middle, where it joins the first branch, and less towards the exterior side of the glabella. The most striking difference between the two forms lies in the structure of the additional pair of furrows, which occurs between the posterior pair, mentioned above, and the neck-furrow. This pair is very distinctly seen, and each furrow is double instead of being single as in *P. rugosa*; thus a narrow raised piece is included between the two forks. The eyes are large and occur in the same position as those of *P. rugosa*. The fixed cheeks are very narrow, but widen out posteriorly to more than  $\frac{2}{3}$  the width of the glabella and have a well-marked neck-furrow. The neck-segment resembles that of *P. rugosa*, but has no central tubercle.

*Locality and Horizon*: Nant-y-Glasdwr, Carmarthen. Tremadoc Slates.

Genus *Ogygia*, Brongn.*Ogygia marginata*, sp. nov. (Pl. XXVI. figs. 13-26.)

This is a fine large species, attaining a length of at least 5 inches, although most of the specimens obtained were not more than  $2\frac{1}{2}$  inches long. The description is of the 'forme longue,' except when otherwise specified.

*General form.*—A true oval, flat, or gently convex; trilobation distinct.

*Head.*—A broad segment of a circle, surrounded by a striated concave border, which is narrower in front, and at the genal angles is produced into long sharp spines. The length of the head as compared with the breadth is about 2:5. The glabella is long, narrow, almost parallel-sided, especially in young specimens, marked off from the fixed cheeks by a deep axial furrow all round. In older forms it is distinctly clavate in front and very slightly contracted in the middle. The surface is flat except for the frontal lobe, which is gently convex. There are traces of two pairs of glabella-furrows, (i) behind the convex frontal lobe, (ii) opposite the base of the eyes. These are very indistinct, and absent in much-compressed specimens. The neck-furrow is incomplete in the middle, and the two side parts of it run backward towards the narrow marginal furrow: thus the occipital ring,—which has a small tubercle in the centre,—is wider than the posterior margin of the fixed cheeks. The corresponding furrows on the fixed cheeks are broad, deep, and quite straight. The fixed cheeks are continuous round the glabella anteriorly; they widen out considerably at each side of the frontal lobe, and also in the middle of the glabella in front, where they follow the course of the facial suture and form a slight point. This portion of the fixed cheeks is convex and is marked with striations similar to those on the anterior margin, which it partially invades. The free cheeks are broad, gently convex, with a fairly wide concave margin, and are produced at the genal angles into long sharp spines. On their inner side is a groove running parallel to the surface of the eye. The eye is situated about halfway up the glabella; it is of medium size, lunate, with the lentiferous surface rather narrow. The facial suture cuts the posterior margin about  $\frac{2}{3}$  of the way out, and is intramarginal in front. It seems to run very near the margin, and forms a small angle in the middle. The hypostome in our specimens is incomplete posteriorly, but is clearly triangular in shape, with a broadly arched base; at the posterior end, where it is narrow, it is traversed by two pairs of deep converging furrows. The duplicature of the margin, as also the hypostome itself, are covered with fine striations. In the middle of the former the 'suture médiane de jonction' described by Barrande is distinguishable.

*Thorax* short, rather less than  $\frac{1}{3}$  of the total length, with eight narrow well-defined segments. Axis narrow, about  $\frac{1}{4}$  the whole width (in the 'forme large,' of which we probably have two specimens, the axis is nearly  $\frac{1}{3}$  the whole width) convex, nearly

parallel-sided. Pleura nearly straight, but slightly bent down at the fulcrum, which is situated about half the distance out; grooved and faceted, also marked beyond the fulcrum by numerous fine striæ. The ends of the pleura are obliquely truncated, but produced posteriorly into short sharp points.

The *pygidium* is more than  $\frac{1}{3}$  the total length and about  $\frac{1}{3}$  broader than long. It is surrounded by a deeply concave striated margin, which is strongly marked off on the inner side by a high convex rim. Axis narrow, tapering gently and ending in a tumid point on the inner rim of the concave margin. It is annulated by six to eight furrows, and the side lobes are marked by a corresponding number of furrows, which reach the inner rim of the margin, where they abruptly terminate.

This species seems to stand halfway between *Ogygia Selwynii*, Salt., and *Ogygia corndensis*, Murch. It differs from *O. Selwynii* in the following respects:—

(i) The head and tail of *O. Selwynii* are equal in length, but in this species the tail is longer than the head.

(ii) The genal spines of *O. Selwynii* are considerably shorter and stouter.

(iii) The hypostome of *O. Selwynii* is broader in proportion to its length.

(iv) The margin of the pygidium in *O. Selwynii* is broader and less concave, and indistinctly marked off from the rest of the tail. The side furrows are also very short. In the new species the furrows are long and extend quite up to the margin, which is marked off by a high convex rim.

It differs from *O. corndensis* in the following respects:—

(i) The axis in *O. corndensis* is throughout a good deal broader, and that of the tail narrows suddenly, so that its sides are curved.

(ii) The margin of the pygidium in *O. corndensis* is indistinctly marked off and is waved by the lateral furrows, which is never the case in this new species.

(iii) The genal spines are slightly longer in *O. corndensis*.

(iv) The glabella in *O. corndensis* is shorter in proportion to its width.

(v) The tips of the pleura in *O. corndensis* are abruptly truncated, and sometimes bluntly rounded, whereas here we have curving sabretips, like those of *O. Buchii*, but shorter.

The feature which marks this species off from other *Ogygiæ* is that the margin is raised in a fold towards the inner edge.

*Localities and Horizons*: Nant-y-Glasdwr, Cwm Ffrwd, Cwrt Hir, Glan Pibwr, Nant Pwntan, etc., Carmarthen. Tremadoc Slates.—Arenig.

## VI. CONCLUSION.

In offering these suggestions with regard to the succession in the neighbourhood of Carmarthen, we feel sure that further evidence will cause many alterations in the boundary-lines which we have drawn between the various series, and we have little doubt that the

area in question is much more faulted than appears in our sketch-map.

Among the problems which demand solution, that of the relations of the Bala Series of Llangunor and Mount Pleasant to the older rocks is perhaps the most important.

A comparison of the position of the grits and conglomerates in the Tremadoc and Llanvirn Beds of Carmarthen with those of the Tremadoc, Arenig, and Llanvirn Series of other British areas would prove valuable, but to draw this comparison satisfactorily we must wait until more exact palæontological correlations can be made.

Our warmest thanks are due to Mr. Marr—by whose advice we undertook this work—for many valuable suggestions with regard to it, and for his help in the identification of some of the specimens.

We also gratefully acknowledge our indebtedness to Prof. Lapworth, who has examined and named some of our graptolites.

## EXPLANATION OF PLATES XXV. & XXVI.

### PLATE XXV.

Geological sketch-map of the neighbourhood of Carmarthen.

Scale: 1 inch = 1 mile.

### PLATE XXVI.

- Fig. 1. *Peltura punctata*, sp. nov. Shows the punctate border and a tubercle on the second body-segment.  $\times 1\frac{1}{2}$ . From the Tremadoc Slates, Nant-y-Glasdwr, Carmarthen.
2. *P. punctata*, sp. nov.  $\times 1\frac{1}{2}$ . Same locality.
  3. *P. punctata*, sp. nov.  $\times 1\frac{1}{2}$ . Same locality.
  4. *P. punctata*, sp. nov. Shows the delicate tips of the pleura.  $\times 1\frac{1}{2}$ . Same locality.
  5. *P. punctata*, sp. nov. A perfect head, somewhat crushed.  $\times 2$ . Same locality.
  6. *P. punctata*, sp. nov. Cast of free cheek.  $\times 2$ . Same locality.
  7. *P. punctata*, sp. nov. A large head; the free cheeks are missing. Natural size. Same locality.
  8. *P. punctata*, sp. nov. Shows the punctate border, the glabella-furrows, the tubercles on the first two body-segments, and the tips of the pleura all distinctly.  $\times 1\frac{1}{2}$ . Same locality.
  9. *P. punctata*, sp. nov. A rolled-up specimen.  $\times 2$ . Same locality.
  10. *P. punctata*, sp. nov. Two pleura enlarged.  $\times 5$ . Same locality.
  11. *Parabolinella*, sp. nov. Head imperfect, the only specimen found. Natural size. Nant-y-Glasdwr, Carmarthen.
  12. *Parabolinella*, sp. nov. Counterpart of portion of fig. 11.
  13. *Ogygia marginata*, sp. nov. Body and tail nearly perfect. Shows the sabre-like tips of the pleura. Natural size. Nant Pwntan, Carmarthen.
  14. *O. marginata*, sp. nov. Possibly the 'forme large' ♀. Natural size. Cwm Ffrwd. Carmarthen.
  15. *O. marginata*, sp. nov. Natural size. Nant Pwntan, Carmarthen.
  16. *O. marginata*, sp. nov. Imperfect glabella. Shows traces of furrows, and a tubercle on the occipital ring. Natural size. Same locality.
  17. *O. marginata*, sp. nov. A young specimen, much distorted. Natural size. Same locality.
  18. *O. marginata*, sp. nov. Shows free cheek and genal spine. Natural size. Same locality.



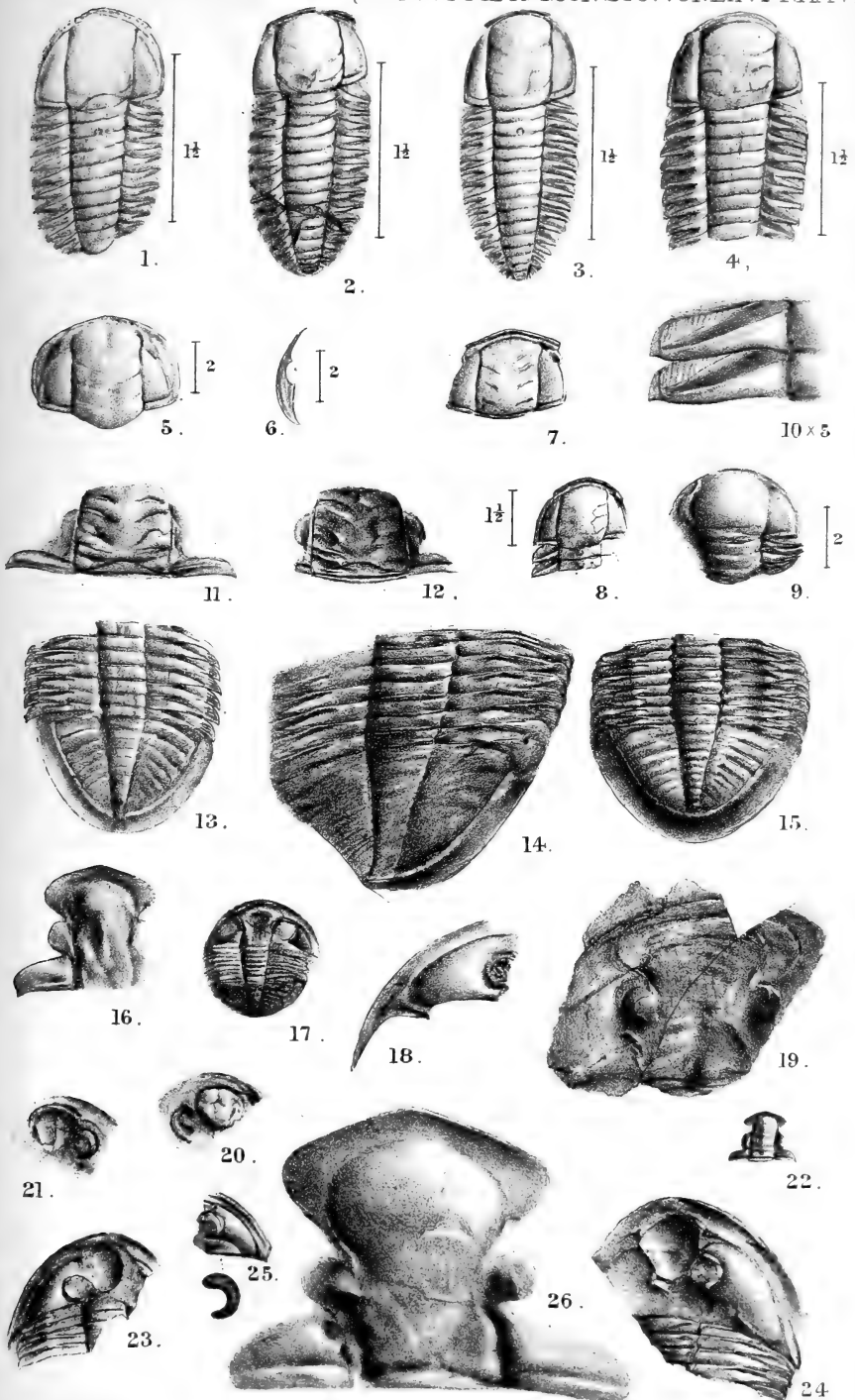




Fig. 19. *O. marginata*, sp. nov. A crushed and distorted specimen. Shows that the course of the facial suture is probably intramarginal. Natural size. Swansea Road stream, Carmarthen.

20. *O. marginata*, sp. nov. Hypostome; imperfect. Natural size. Glan Pibwr, Carmarthen.

21. *O. marginata*, sp. nov. Counterpart of fig. 20.

22. *O. marginata*, sp. nov. Glabella of a very small specimen. Shows the tubercle on the occipital ring. Natural size. Glan Pibwr, Carmarthen.

23. *O. marginata*, sp. nov. Shows the hypostome and free cheek. Natural size. Nant Pwntan, Carmarthen.

24. *O. marginata*, sp. nov. Ditto. Same locality.

25. *O. marginata*, sp. nov. Shows the eye and part of the facial suture. Natural size. Glan Pibwr, Carmarthen.

26. *O. marginata*, sp. nov. The glabella of a large specimen. Natural size. Same locality.

#### DISCUSSION.

The PRESIDENT congratulated the Authors on the important discoveries which they had made. The finding of Tremadoc rocks in the neighbourhood of Carmarthen was a fact of great importance, and might lead to the discovery of still older rocks in that area. The succession closely resembled that found in Pembrokeshire; but it was now carried farther east than had previously been done, though the work of the late T. Roberts and Mr. Marr had led one to anticipate that rocks at least as old as those of Arenig age would be found in this area.

Dr. WOODWARD congratulated the Authors on the admirable series of fossils which they had collected, and especially on the very beautiful species of trilobites which they had added to the British fauna, in particular the specimens of *Peltura punctata* and *Ogygia marginata*. The latter form recalled to him the *Asaphus* (*Ptychopyge*) *cornidensis*, Murch., referred to by Wyatt-Edgell (Geol. Mag. 1867, pp. 14-15), but this species is from the Llandeilo Beds, not from the Tremadoc.

Mr. MARR stated that the work done by the late T. Roberts and himself (and no doubt also the work of the Authors of the present paper) was largely facilitated by the published maps of the Geological Survey. He believed that the Tremadoc age of the beds claimed as of that date was thoroughly established. The *Dicranograptus*-shales had hitherto yielded Hartfell graptolites only. He believed that Glenkiln forms had been discovered by Mr. Roberts and himself in the Haverfordwest area, but they were very badly preserved and not really identifiable. They should be looked for elsewhere.

Mr. HOPKINSON and Dr. HINDE also spoke.

32. *On the CLASSIFICATION of the STRATA between the KIMERIDGIAN and APTIAN.* By Dr. ALEXIS P. PAVLOW, For. Corr. G.S., Professor of Geology in the University of Moscow. (Read March 25th, 1896.)

## [PLATE XXVII.]

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## I. SCHEMES OF CLASSIFICATION.

IN the paper on the Speeton fauna, forming a part of the work which I wrote in conjunction with Mr. G. W. Lamplugh, I attempted to correlate the Upper Jurassic and the Lower Cretaceous horizons of Speeton with their equivalents in Russia and in different parts of Europe, and to give a general scheme of classification of these beds. This scheme may be briefly stated as follows.

The Kimeridgian zone of *Hoplites pseudomutabilis* and *Aspidoceras acanthicum* is common to different countries of Europe. Above this zone in the Meridional province repose the marine beds of the Tithonic stage, terminating the Jurassic. These beds comprise two substages—the Lower Tithonic, which contains two fossil-zones; and the Upper Tithonic, also containing two zones. To this Tithonic stage corresponds in Southern England the Portland stage *sensu lato*, including the Lower marine series (Portland, *sensu stricto*, or Bononian Series), and the Upper freshwater Portland or Purbeck. In Northern France and partly in Southern England three fossil-zones can be distinguished in the marine Portland, namely, the zone of *Ammonites portlandicus* and *Bleicheri*, the zone of *Virgati*, and the zone of *A. giganteus*. In Yorkshire the equivalents of this series are condensed, and moreover the freshwater Purbeck is replaced by marine beds with *Belemnites lateralis*, deposited in a separate boreal marine basin. To designate these uppermost horizons of the Jurassic in its marine development, I proposed the name ‘Aquilonian’ stage or substage, including in this term the zone or zones of *Ammonites fragilis* and *nodiger* and the zone of *Polyptychites* (*Keyserlingi*, *gravesiformis*, etc.). The last-mentioned zone, being the uppermost of the Tithonic stage, was described as being characterized by the presence in its fauna of many Cretaceous elements.

In Russia the equivalents of the marine Portland of France and the Aquilonian stage are well represented and rich in cephalopoda—those most trustworthy guides in the deductions of comparative stratigraphy. To the zone of *Polyptychites Keyserlingi*, *gravesiformis*, etc., with its many Cretaceous fossils, the name of ‘Petchorian’ was applied, and in the general scheme this was placed at the top

of the Aquilonian stage. Notwithstanding the presence of numerous Cretaceous species in these beds in Russia and in England, I found it on the whole more convenient to class them as Jurassic, noting, however, that they formed the uppermost Jurassic strata, lying at the extreme limit of the two systems. In adopting this view I was guided by the following considerations. Both in Russia and in England the fauna of this horizon is more closely related to the fauna of the underlying than to that of the overlying beds; and also the undoubtedly Neocomian fossils, such as *Ammonites Astieri*, *Hoplites regalis*, *Belemnites pistillirostris*, etc., are found only above this horizon, their appearance bringing all at once a new element into the fauna. Moreover, the Cretaceous species recognized among the representatives of the genus *Polyptychites* in the Petchorian strata had mainly been found in the Hils Beds of Germany, whose stratigraphy has been incompletely studied.

My scheme of the Russian subdivisions indicated that there was a well-marked stratigraphical and faunistic break between the zone of *Polyptychites Keyserlingi* and the Simbirskian Neocomian beds, with *Simbirskites versicolor*, *Decheni*, and *discofalcatus*, which latter represented apparently the boreal development of the Upper Neocomian with possibly also the upper part of the Middle Neocomian; and that the beds with *Hoplites regalis* and *Astieria Astieri* were absent in Russia. But there were still other horizons, not strictly defined palæontologically and stratigraphically, which by their position, as it was then understood, might be regarded as lying near the limit between the Jurassic and Cretaceous systems. The fauna of one of these horizons displayed an affinity to the Upper Tithonic fauna, and the fauna of another was closely related to that of the zone of *Polyptychites Keyserlingi*. I refer here to the zone of *Hoplites riasanensis*, and to that of *Olcostephanus hoplitoides* of the government of Riasan. I had not then the necessary material for defining strictly the position of these horizons in the stratigraphical series, but I presumed that one of them, namely the zone of *Olcostephanus hoplitoides*, might represent a Lower Neocomian horizon of a still unknown boreal type, and that the other—that is, the zone of *Hoplites riasanensis*—might represent a mixed type of the Lower Neocomian.

Shortly after the publication of these results it was demonstrated, by my further researches and the palæontological studies of M. W. Stechirowsky<sup>1</sup> in the Geological Museum of Moscow, that in the northern part of the government of Simbirsk (districts of Alatyr and of Kurmysh) there exists a horizon the fossils of which show affinities both with the zone of *Craspedites subditus* and *nodiger*, and with that of *Polyptychites Keyserlingi*. Having seen the great interest which attached to the study of these horizons, I entered upon new researches, in the zones both of *Olcostephanus hoplitoides* and of *Hoplites riasanensis*, in the region of their greatest develop-

<sup>1</sup> 'Ueber Ammoniten der Genera *Oxynoticeras* und *Hoplites* aus dem nord-simbirsk'schen Neocom,' Bull. Soc. Imp. Nat. de Moscou, n. s. vol. vii. (1893) p. 369.

ment, in the government of Riasan, and these were at the same time studied by M. Bogoslowsky.<sup>1</sup>

As the result of these researches, I am now enabled to give a more complete and correct scheme of the Upper Jurassic and Lower Cretaceous succession in Russia, or, in other words, in the Boreal province. The study of the close of the Jurassic and the beginning of the Cretaceous times in this region helps largely in the determination of the position of the different horizons of the same series in other countries, especially in England and Germany; and the further working out of the common classification of these beds may be thus facilitated.<sup>2</sup>

The grounds on which this new scheme is based are as follows. My researches near Kashpur, in the district of Syzran, have shown that below the horizon of *Polyptychites polyptychus*, *Keyserlingi*, *syzranicus*, and between this horizon and the zone of *Craspedites kashpuricus* and *Oxynoticeras subclypeiforme*, there exists a bed of sandy marl (about 1 metre in thickness) very rich in *Aucella*, especially *Aucella volgensis*. This bed, which has both above and below it a small seam of glauconitic sand, includes (along with some fossils proper to the zone of *Polyptychites Keyserlingi*) a series of especially characteristic forms, which are known also from the before-mentioned bed in the districts of Alatyř and Kurmysh, including *Ammonites stenomphalus* and *Marcousanus*. Owing to the close relations of the bed with the zone of *Polyptychites Keyserlingi*, I find it convenient to unite it therewith, and to apply to both the name of the Petchorian Series; and this is the more convenient, since, judging from a collection of fossils not yet described, brought to me by M. A. Ivanow from the region of Petchora, and also from some literary data, both faunas exist there in closely related beds. At Kashpur both the lower and the upper zones of the Petchorian Series can be distinguished, and both are rich in *Belemnites lateralis*, *subquadratus*, and *russiensis*. In the districts of Kurmysh and Alatyř only the lower zone has been discovered, and M. Stchirovsky, who has described a part of its fauna, has recorded therein such forms as *Oxynoticeras Gevřilianum* and *Marcousanum*, which are generally regarded as Lower Neocomian. Such forms are, however, very rare among the numerous and entirely new species of ammonites, more or less nearly related to *Ammonites stenomphalus*. (I am now engaged in describing this remarkable fauna.)

The presence, though very rare, of Lower Neocomian types in this zone is an argument in favour of considering the whole

<sup>1</sup> A. Pavlow, 'On the Mesozoic Beds of the Government of Riasan,' Report of the Geological Excursion undertaken in the summer of 1893, Scient. Rec. Imp. Univ. Moscow, sect. Nat. Hist. pt. ii. (in Russian); N. Bogoslowsky, 'Volgian, Upper Tithonic, and Neocomian Beds in the Government of Riasan,' Preliminary Report, Materialien zur Geologie Russlands, vol. xvii. 1895 (in Russian).

<sup>2</sup> The correlation of these beds in the different countries of Europe was the subject of a communication made by me to the International Geological Congress at Zürich in 1894.

Petchorian Series, that is, the zones of *Ammonites stenomphalus* and of *Ammonites Keyserlingi*, as being the Lower Neocomian of Boreal type, notwithstanding the affinity of their fauna with that of the underlying zones of the Aquilonian, of which the Jurassic age is thus more strongly defined.

But if it should prove locally inconvenient to fix the lower limit of the Cretaceous at a lower level than the base of the zone of *Hoplites neocomiensis* and *regalis*, then these Petchorian beds and their equivalents may be considered as an intermediate series between the two systems, to be placed either with the Jurassic or with the Cretaceous, after the stratigraphical and faunistic relations of the beds with *Ammonites Marcousanus* and *Gevrilianus* of Central Europe have been thoroughly studied, and their equivalents and relationship to the underlying and overlying beds more completely understood. This, however, seems to me a less convenient course than that which I have proposed above, since it still leaves the limits of the systems indefinite, though no doubt it might in some countries suit better the local conditions as displayed in the lithological or palæontological sequence.

In the Syzran region the next underlying horizons to the beds above described are a thin band (20 centimetres) of bituminous shale and a thin band of greenish sand, both very poor in fossils; and still lower come a sandstone and conglomerate with *Aucella volgensis*, *trigonoides*, *Fischeri*, *Ammonites kashpuricus*, *subclypeiformis*, and many other ammonites allied to *nodiger* and *kashpuricus*.

In the government of Riasan the succession of the Upper Jurassic and Neocomian beds is as follows:—The beds with *Cardioceras alternans* are overlain by a thin band of glauconitic sand and phosphatic nodules containing several species of *Virgatites*. This bed thins out here and there, and is reduced to a narrow band of phosphatic nodules only (as at Speeton). The next bed is a glauconitic sand, with *Ammonites fragilis* and *catenulatus* and phosphatic sandstone with *A. kashpuricus*, *subclypeiformis*, *Belemnites mosquensis*, many species of *Aucella* (*mosquensis*, *Fischeri*), etc. This bed is very thin, and passes insensibly upwards into the zone of *Hoplites riasanensis*, without changing its lithological character.<sup>1</sup> This passage is indeed indicated only by the substitution of the forms of the group of *Hoplites riasanensis* for *Ammonites kashpuricus* and *subclypeiformis*, the rest of the fauna remaining almost unchanged. The same *Belemnites* and *Aucellæ* form a characteristic feature in the fauna and impress upon it a boreal character, which contrasts markedly with the meridional type of certain of the *Hoplites* more or less resembling Upper Tithonic forms. This occurrence of Upper Tithonic forms at the top of the zone of *Craspedites kashpuricus* and *Oxynticeras subclypeiforme*, constituting the uppermost zone

<sup>1</sup> These relations are to be seen at the village of Kusminskoie. There are other places (Old Riasan) where the *nodiger*-zone, and even the *catenulatus*-zone, is absent, and the bed with the *Hoplites riasanensis*-group is much thicker than at Kusminskoie. Possibly such cases indicate that the *riasanensis*-fauna appeared there somewhat earlier.

of the so-called Volgian stages, shows clearly the Jurassic age of both of these stages, and cuts the ground from under the feet of the defenders of the Cretaceous age of one or both of these stages.

This bed, with *Hoplites* of the *riasanensis*-group, thus capping the Upper Jurassic Series, passes upwards in its turn into a glauconitic sandstone with the fauna of the lower zone of the Petchorian, that is to say, of the boreal Lower Neocomian series. The *Hoplites* of the *riasanensis*-group, though rare, continue to be met with in this bed, which contains also a great number of *Aucellæ* (especially *A. volgensis*) and *Belemnites* of the *lateralis*- and *subquadratus*-groups. This bed is, in turn, capped by sands containing rough sandy phosphorites with *Olcostephanus hoplitoïdes*, representing the upper zone of the Petchorian Series, that is, the zone of *Polyptychites polyptychus* and *Keyserlingi*, and we find there many forms common to the corresponding horizon of Syzran and of the Petchora region. The fauna of this second horizon of the Petchorian is very rich and varied. Its most characteristic fossils are ammonites of the group *Polyptychites*, belemnites of the *lateralis* and *subquadratus* groups, and some species of *Trigonia*. *Aucellæ* are very rare in this zone in the government of Riasan. Recently I have found in it a fragment of *Hoplites neocomiensis*, which facilitates the correlation of the zone, and of the whole Petchorian, with the corresponding zones of the Lower Neocomian of Western Europe.

Thus we have in Russia a well-developed 'Aquilonian' stage, corresponding to the Purbeck, and an equally well-developed 'Lower Neocomian,' having many species in common with the West European Lower Neocomian but bearing a special stamp, expressed in the presence of fossils of boreal type, especially of many species of *Aucellæ* (partly undescribed) and of belemnites of the *subquadratus* and *lateralis*-groups. This boreal Lower Neocomian (Petchorian Series) bears a close faunistic relation to the underlying Jurassic rocks of the Aquilonian stage, and is in Russia marked off by a well-defined break from the Upper Neocomian (beds of Simbirsk), the intermediate beds of Speeton with *Hoplites regalis* being here absent.

The Russian Lower Neocomian is, moreover, subdivided into two zones: (1) The lower zone of *Olcostephanus stenomphalus*, corresponding to the zone of *Ammonites Marcousanus*, and indeed containing rare representatives of this species; and (2) The upper zone of *Polyptychites polyptychus* and *Keyserlingi*, corresponding to the zone of *Hoplites neocomiensis* and containing very rare representatives of this species.

The Aquilonian stage, which is the marine equivalent of the Purbeck, is also subdivided into the following zones (from below): (1) zone of *Ammonites fragilis*, *subditus*, and *catenulatus*; (2) zone of *A. nodiger* and *subclypeiformis*; (3) zone of *Hoplites riasanensis*. All these zones are so related to each other by the presence of the same *Belemnites* and *Aucellæ* as to form a natural group, corresponding to the Purbeck and to the Upper Tithonic, and containing in the uppermost zone forms with Neocomian affinities.



Turning now to the consideration of the subdivisions of the same series in other countries, I cannot add much to the correlations already published in my paper on the Speeton fauna.

As regards England, we see now that the Neocomian is here more completely developed than in Russia, the zone of *Hoplites regalis* being well represented at Speeton. If, however, we begin the Neocomian with the bed containing *Ammonites plicomphalus* and ammonites of the group of *Polyptychites*, the beds  $D_{1-3}$  of Speeton must be carried over to the Neocomian. I regard it as possible that at some future time two distinct zones will be distinguished there, corresponding to the zones of *Ammonites stenomphalus* and of *Polyptychites Keyserlingi*. In Lincolnshire the Claxby Ironstone should probably be considered as Cretaceous, while the greater part of the Spilsby Sandstone appears to belong to the Upper Jurassic (Aquilonian).

In Germany all the zones of the Neocomian seem to exist (a good specimen of *Simbirskites progrediens*, from Salzgitter, is preserved in the Göttingen Museum), but the stratigraphy of the beds presents many difficulties and requires further researches. I am therefore able to give only a provisional classification of the faunistic sequence of this region. (See Table facing p. 548.)

In the southern regions of Europe we have to consider the question of the Upper Tithonic and Berrias beds. In Russia the *Hoplites* closely related to Upper Tithonic types make their appearance in the uppermost zone of the Aquilonian, and in one region (government of Riasan) some rare forms continue into the lower zone of the Lower Neocomian. When this fauna shall have been sufficiently studied, it promises to yield very interesting results, since very nearly allied, and possibly identical, ammonites have been found in South America,<sup>1</sup> and perhaps in Tibet. As for the Berrias of Southern Europe, I am inclined to consider that this horizon, from its close faunistic connexion with the Upper Jurassic, should be ranged with that system. But since some Lower Neocomian forms are found in it, and since in many areas it has been customary to carry even the whole Berrias into the Cretaceous, it may be found convenient, for the sake of working out a common classification, to divide this transitional series between the two systems, placing the Ardescian (with the Lower Berrias) with the Jurassic, and the uppermost Berrias with the Cretaceous. This question must, however, be further studied in the region where the typical Ardescian and Berrias are fully developed, and especially in the northern part of that region.

For the solution of this question it is necessary that one should find the fauna with *Hoplites Malbosi*, *Euthyni*, etc., and also the fauna with *Oxynoticeras Gevriianum* and *Marcousanum*, in one and the same section, so that the mutual relations of these two faunas could be exactly studied; and this appears to be a very delicate and difficult task.

<sup>1</sup> *Hoplites mendozanus*, Zeitschr. d. Deutsch. geol. Gesellsch. vol. xliii. (1891) p. 399 & pl. xxv. fig. 2.

The scheme illustrated in the accompanying Table has been drawn up to illustrate the correlations of the beds above discussed, in the light of our present knowledge. Naturally, I have found it possible to give more details regarding the Russian than the foreign beds.

In Russian literature the name 'Volgian' stage or stages is still applied to designate certain beds of the series in question, namely the beds ranging from the *virgatus*-zone of Portland to the *nodiger*-zone of the Aquilonian. Many other divisions of our series have been supposed to be contemporaneous with parts of these zones; for instance, the bed with *Hoplites riasanensis* of the government of Riasan has been correlated with the zone of *Virgatites virgatus*, and the bed with *Olcostephanus hoplitoides* of the same region has been held to be contemporaneous with the *nodiger*-zone. The explanation of these views will be found in tracing the growth of our knowledge of these deposits. Prof. Rouillier established in 1845 the divisions of *virgatus* and *catenulatus*-beds, otherwise called the Middle and Upper Moscovian stages,<sup>1</sup> and strictly-defined geographical types were indicated for each of them. The further progress of research in this branch of Russian geology was directed to the investigation of the geographical extent of these stages and to the study of their fauna. Prof. Neumayr, in his remarkable work, 'Die Ornatenthone von Tchulkowo und die Stellung des Russischen Jura' (1876), being without sufficient evidence to fix the position of these stages in the stratigraphical series, expressed the opinion that they might represent a peculiar group of beds formed in the Russian basin after its separation from the West European sea. These two stages were soon afterwards united under the common name of the 'Volgian stage' (from the vast Volga basin), and this new title supplanted the previous names. From this time there was a growing tendency to include in the 'Volgian stage' all the Upper Jurassic and Lower Cretaceous beds whose geological age was not strictly defined, and hence it followed that various horizons were from time to time considered to be contemporaneous sometimes with the *virgatus*-beds and sometimes with the *catenulatus-nodiger*-beds. Under these conditions it was inevitable that there should be introduced into the Volgian stage very different horizons of the Jurassic and of the Cretaceous; and after a short time this stage was divided anew into two separate stages—the 'Lower Volgian,' corresponding to the *virgatus*-beds of Rouillier, and the 'Upper Volgian,' corresponding to the *catenulatus-nodiger*-beds of the same author. The fluctuation of opinions which has taken place respecting the age and extent of these stages is very natural, since the term 'Volgian' was sometimes applied to all the Upper Jurassic rocks down to the base of the Kimeridgian or even of the Oxfordian; sometimes to the Upper Jurassic and the Lower Cretaceous, between

<sup>1</sup> Prof. Rouillier, Bull. Mosc. iv. (1845), even distinguished two ammonitic zones in his Upper stage, but the characteristic ammonite of the Upper of these (*Ammonites nodiger*), not having then received a specific name, was called *Ammonites*, sp.

## LATION OF THE RU

SK.	MOSCOW.	BOULOGNE AND SOUTHERN ENGLAND.	NORTHERN REGION OF ENGLAND.	SOUTH-EASTERN FRANCE.
shales. <i>shayesi</i> .	Sands and sand with plant-remains. Sparrow Hills rowo, Klin.	Hythe and Sandgate Beds.	Tealby Limestone, beds B of Speeton. <i>Hoplites Deshayesi</i> , <i>Belemnites brunsvi-</i> <i>gensis</i> .	Beds with <i>Hoplites</i> <i>Deshayesi</i> and <i>Acanthoceras Mar-</i> <i>tini</i> .



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the Kimeridgian and the Upper Neocomian; and sometimes it was held to be entirely Neocomian. Under these circumstances, it appears to me advisable to avoid this term altogether, the more so that all the beds heretofore included under it have now been relegated to their natural place in the general classification, which is the Upper Jurassic. It was for the above reason that I found it necessary to introduce in my former work the provisional name 'Série Speeton-russe' for the beds overlying the Kimeridgian and terminating with the zone of *Polyptychites Keyserlingi*. (See p. 532 in Bull. Soc. Imp. Nat. Mosc. n. s. vol. v. 1891, or p. 174 sep. cop.)

## II. ON THE ENGLISH AND GERMAN SPECIES OF *AUCELLA*.

The casts of the English specimens of *Aucella* to be described were in part obtained by me during my visit to the Woodwardian Museum at Cambridge in 1888, and in part were sent to me with the ammonites described in my work on the Speeton fauna, through the kindness of Prof. T. McKenny Hughes, F.R.S. The German specimens and casts I owe to the kindness of Prof. A. von Koenen, of Göttingen, of Herr O. Weerth of Detmold, and of the Rev. Pastor Denkmann of Salzgitter.

The representatives of the genus *Aucella* have been found in England at two different horizons. The lower of these is the Lower Portlandian bituminous shale of Central England (Upper Kimeridge shale of English geologists), from which have been obtained some specimens of *Aucella Pallasi* now preserved in the Woodwardian Museum. Two of these specimens are figured in my paper, 'Jurassique supérieur et Crétacé inférieur de la Russie et de l'Angleterre,'<sup>1</sup> and I have nothing further to add to my former description of them. Those which occur at the higher horizon are dealt with in the following notes.

*AUCELLA VOLGENSIS*, Lahus., 'Ueber die russischen Aucellen,' Mém. du Comité géologique, vol. viii. no. 1 (1888), p. 38, pl. iii. figs. 1-17.

The English form (Pl. XXVII. figs. 1*a*, 1*b*, 1*c*) corresponds well with the characters of this species established on Russian specimens, and from any large collection of such specimens it is not difficult to pick out individuals in all respects similar to the English form, so that it is impossible to doubt the identity of the Russian and English species. In Russia, *Aucella volgensis* is most abundant in the zone of *Ammonites stenomphalus* and *A. Marcousanus*—that is, in the lowest zone of the boreal Neocomian. The English specimen is preserved in the Woodwardian Museum at Cambridge. It bears the old label '*Inoceramus imbricatus*, Lower Greensand, Donnington,' and its matrix shows that it has been obtained from the Spilsby Sandstone. This form seems to exist also in Germany.

<sup>1</sup> Bull. Soc. Imp. Nat. Moscou, n. s. vol. iii. (1889) pl. iii. figs. 4 & 5, p. 106 (p. 48 in sep. copy).

I have two specimens apparently belonging to this species, but too badly preserved to be identified with certainty. They come from the Maria Grube at Steinlach.

*AUCELLA VOLGENSIS*, var. *RADIOLATA*. (Pl. XXVII. figs. 2 a 2 b.)

In outline this is very like the typical *Aucella volgensis*, but is distinguished by the feebly marked longitudinal streaks which intersect the more marked concentric folds. A feebly pronounced longitudinal hollow in the back part of the larger valve may also be noted as characteristic of this variety, though less constant, as appears from Russian specimens. In the Woodwardian Museum collection this specimen was labelled as follows:—‘*Inoceramus imbricatus*, Bean MS., Donnington, Lower Greensand’: it is in a Spilsby Sandstone matrix. In Russia this variety occurs at the same horizon as the preceding form. Judging from some fragments of *Aucella* that I have obtained from Eheberg, near Oerlinghausen, the existence of this variety in Germany is probable.

*AUCELLA KEYSERLINGI*, Lahus., ‘Ueber die russischen Aucellen,’ Mém. du Comité géologique, vol. viii. no. 1 (1888), p. 40, pl. iv. figs. 18–23.

The English specimen of this species (Pl. XXVII. figs. 3 a, 3 b, 3 c), from the Woodwardian Museum, has the shell preserved, and can be defined with certainty. It bears a label: ‘Claxby. Tealby Series. *Inoceramus imbricatus*.’ The matrix is Claxby Ironstone. In Russia this species is very numerous in the zones of *Ammonites stenomphalus* (Lower Petchorian). In Germany it is also far from rare. I have seen many specimens of it in the Göttingen Museum, in the collection of the Rev. Pastor Denkmann at Salzgitter, and in the collection of Herr O. Weerth at Detmold. The German specimens are very fine; they come from the Maria Grube at Steinlach, near Salzgitter, and from Eheberg, between Oerlinghausen and Bielefeld. This seems to be the commonest species in Germany.

*AUCELLA TEREBRATULOIDES*, Lahus., *ibid.* p. 39, pl. iv. figs. 1–9.

In the Woodwardian Museum a specimen of this species is preserved, which in size and sculpture is very like that figured by Prof. Lahusen in pl. iv. fig. 2, *op. cit.* I have not figured this specimen.

Beside the above, in Germany other species occur—for instance, *Aucella (Avicula) teutoburgensis*, Weerth, which differs from all the species above mentioned. In another note I propose to give my opinion concerning this species and its relations to the other forms of *Aucella*.

The presence of identical species of *Aucella* in England, Germany, and Russia more closely connects the corresponding beds of these countries, as will be seen below.



## III. GENERAL CONSIDERATIONS.

Let us now, by the light of these results, glance at the course of geological events in our region during the final stages of the Jurassic epoch and the beginning of the Cretaceous.

In Kimeridgian time over Eastern and partly over Central Russia there existed an extensive sea, communicating with the West European Kimeridgian sea and stretching to the east and north-east far beyond the boundaries of Europe.<sup>1</sup> In this basin were developed certain ammonites, appearing in the West European sea as 'cryptogenic' types.<sup>2</sup> The fauna of the Russian Kimeridgian sea, though possessing a general resemblance to the West European fauna, exhibits many peculiarities of its own, as, for instance, the abundance of the belemnites of the *Magnifici* and *Explanati*-groups, the abundance of *Cardioceras* (*C. subtilicostatum*, *C. Volgæ*) and the presence, though rare, of *Aucella*.

In Central Russia, at the end of the Kimeridgian age, the sea disappeared, and there occurred a certain amount of destruction of the Kimeridgian beds,<sup>3</sup> but in Eastern Russia a further evolution and migration of faunas took place, and the ammonites of the *Bleicheri*-group came into existence (derived probably from the Kimeridgian *Perisphinctes*), and *Belemnites magnificus*, *Troslayanus*, and *explanatus* appeared as the descendants of *Belemnites Oweni*, *Panderi*, and *brevi-axis* of the previous period. In Western Europe the fauna of this sea, separated for a time by a tract of land, evolved some peculiar characteristics, and there appeared certain cryptogenic ammonites in it, such as *Ammonites portlandicus* (*gigas*). With the beginning of the *Virgatites* epoch, a new 'hydrocratic' displacement of the shore-lines brought the sea again into Central Russia and even farther into Poland, and there was a communication between this Russian sea and that of the West European Bononian, and apparently also that of England. In this manner we seek to explain the presence of *Virgatites* in the Portlandian of Boulogne, the presence of *Aucella Pallasi* in the Lower Portlandian (Upper Kimeridgian of English authors) shales of Spilsby, and the presence of the fragments of *Virgatites* and *Belemnites*, cf. *absolutus* in the Lower Coprolite-bed of Speeton.

The physical conditions of the region remained without great change in the succeeding age of *Ammonites giganteus*, but the *Aucellæ* seem to be absent or very rare at this time in Western Europe, probably owing to some conditions unfavourable to their existence or to the presence of some inimical forms of animal life in this region.

In the northern part of England an interruption of sedimentation

<sup>1</sup> Witness the *Aucellæ* in the Kimeridge Clay of the Volga region and of the Petchora region, and certain faunistic affinities between the Kimeridgian *Hoplites* of Eastern Russia and some of the ammonites of Tibet.

<sup>2</sup> Neumayr, 'Ueber unvermittelt auftretende Cephalopodentypen im Jura Mittel-Europas,' Jahrb. d. k.-k. geol. Reichsanst. vol. xxviii. (1878) p. 37.

<sup>3</sup> Hence the occasional discovery of Kimeridgian *Hoplites* in the Portlandian phosphatic nodules and in the Boulder Clay.

seems to have taken place at this time, during which the *Virgatites*-beds were destroyed so as to leave only a band of phosphatic nodules, with fragments of *Virgatites* and *Belemnites*.

At the end of the Jurassic period in the region of Southern England, Northern (and Central) France, and Northern Germany well-marked 'geocratic' movement took place, and, as the result of this, the Purbeck continent arose and separated the northern (Aquilonian) from the southern (Tithonic) Sea. This event, however, did not occur simultaneously throughout this large region; the German part of it seems to have emerged earlier than the rest, probably at the beginning of the *virgatus*-age. Some parts of Russia (the southern part of the government of Nijni-Novgorod and the northern part of the government of Simbirsk) likewise emerged approximately at the same time, and remained dry land until the epoch of the Lower and (in some places) of the Upper Neocomian; but no freshwater beds were deposited there. In other parts of Russia the sea did not disappear until later (at the *catenulatus-nodiger* age), and reappeared in Upper Neocomian time (Simbirsk).

In the district of Syzran there is a region where the Aquilonian beds seem to pass, without any noticeable break, into the Lower Neocomian (Petchorian), the beginning of which is marked by the appearance of new ammonites of the *stenomphalus*-group. Last of all there is a region in Russia where the first traces of the submergence of the Purbeck continent at the end of Aquilonian time (in some localities, it would seem, at a somewhat earlier time) can be observed, and this event is marked by the sudden appearance of ammonites of the *Hoplites riasanensis*-group amidst the typical Aquilonian fauna in the governments of Riasan and of Moscow. But that was only a short and local episode in the life of this fauna, and soon afterwards a boreal Lower Neocomian fauna with ammonites of the *stenomphalus*-group (*Aucella volgensis*, *A. Keyserlingi*, *Belemnites subquadratus*, etc.) coming from the east and north-east took possession of the Riasan region.

At the same time—that is, a little later than in Central Russia—the Lower Neocomian boreal sea stretched over Germany, where it accumulated the lowermost beds of the Neocomian with *Ammonites Gevritianus* and *A. Marcousanus* and penetrated to Central England (depositing the beds with *Aucella volgensis*, *A. Keyserlingi*, *Ammonites stenomphalus*). This seems to be the first zone laid down after the partial disappearance of the Purbeck continent of Western Europe. The next zone of the boreal Neocomian, that of *Polyptychites Keyserlingi*, *gravesiformis*, *Beani*, etc., possesses a very wide extension—from Yorkshire and Lincolnshire, through Germany and Central Russia, far into the North-east. In Central Russia this zone bears a very well-marked littoral character, being represented by sands and conglomerates, and being in some places absent. During the deposition of this zone, but apparently not until towards the end of it, and therefore much later than in Central Russia, we find in England, and probably in Germany also, the

first traces of a new 'hydrocratic' displacement of the shore-lines, by which a further part of the Purbeck continent disappeared and communication with the southern sea was opened. Thus were the first pioneers of the southern fauna permitted access to the Northern basin; and in the succeeding zone of *Hoplites regalis* this fauna took possession of the region and supplanted the Northern species. There still remained, however, a considerable portion of the pre-existing continent, and this formed the Wealden land-area. Now let us consider what had happened meanwhile in the Eastern Russian part of our region.

As the Table (facing p. 548) shows, the Petchorian beds are overlain in Russia by the Upper Neocomian (Simbirskian) beds with *Simbirskites versicolor*, *discofalcatus*, *Decheni*, etc., and in no part of Russia are the beds with *Hoplites regalis* known. We may conclude from this that by the time when the 'hydrocratic' movement, which began in Central Russia, had reached the western portion of Europe and had opened there a communication between the northern and southern basins, Central Russia itself had once more become dry land, and remained so until Upper Neocomian times, at which period, in consequence of renewed 'hydrocratic' movements, an extensive sea again covered North-eastern, Eastern, and in part Central Russia. In England and probably in Germany, during the same Upper Neocomian epoch, a boreal fauna regained the advantage over the southern invaders, and beds with *Simbirskites speetonensis*, *Decheni*, *subinversus*, etc., were deposited. It is, moreover, interesting to note that precisely at this period a few forms of *Simbirskites*—the characteristic representatives of the boreal fauna—penetrate far to the south and appear amidst the southern fauna in the Crimea and even in Southern France. During the succeeding stages of the Aptian and of the Gault a common fauna of mixed character establishes itself widely, but in Western Europe we observe in it the predominance of southern forms, such as *Acanthoceras Martini*, *Belemnites minimus*, and other allied species, results due probably to a new 'geocratic' displacement of the shore-lines in Central Russia, and to the rising of Aptian dry land, on which the plant-bearing sands and sandstones of the Sparrow Hills, of Tatarowo, and of Klin (government of Moscow) were accumulated.

From this sketch it becomes apparent that the 'hydrocratic' and 'geocratic' movements of the shore-lines did not take place simultaneously over the whole of this vast area, but that each movement passed slowly through the region latitudinally. And it is this great march of movements—whether of solid crust or of sea-level it matters not—that has brought about the complicated sequence of the different faunas in the different parts of the region above described. Whence it follows that only by taking into consideration the course of events over the whole of the region can we hope to obtain a general and intelligible picture of this particular chapter of geological history in any country which formed part of it. It is, however, only on the results of detailed local studies that any successful attempt to classify the events must be based.

I am well aware that the present is a vague and incomplete sketch of the subject, but it may serve to turn the attention of my co-workers to the places and questions especially interesting from this point of view, and thus lead in the future to a more satisfactory grouping of the geological events of the period. From a broader standpoint it shows, too, how in different countries the subdivisions of a series of beds may replace one another in regular sequence, allowing us to follow out the ever-changeful development of the earth's surface from one epoch to the next.

#### EXPLANATION OF PLATE XXVII.

[The figures are all of the natural size.]

- Figs. 1 *a*, 1 *b*, 1 *c*. *Aucella volgensis*, Lahus. Lower Greensand, Donnington.  
 „ 2 *a*, 2 *b*. *Aucella volgensis*, var. *radiolata*. Lower Greensand, Donnington.  
 „ 3 *a*, 3 *b*, 3 *c*. *Aucella Keyserlingi*, Lahus. Tealby Series, Claxby.

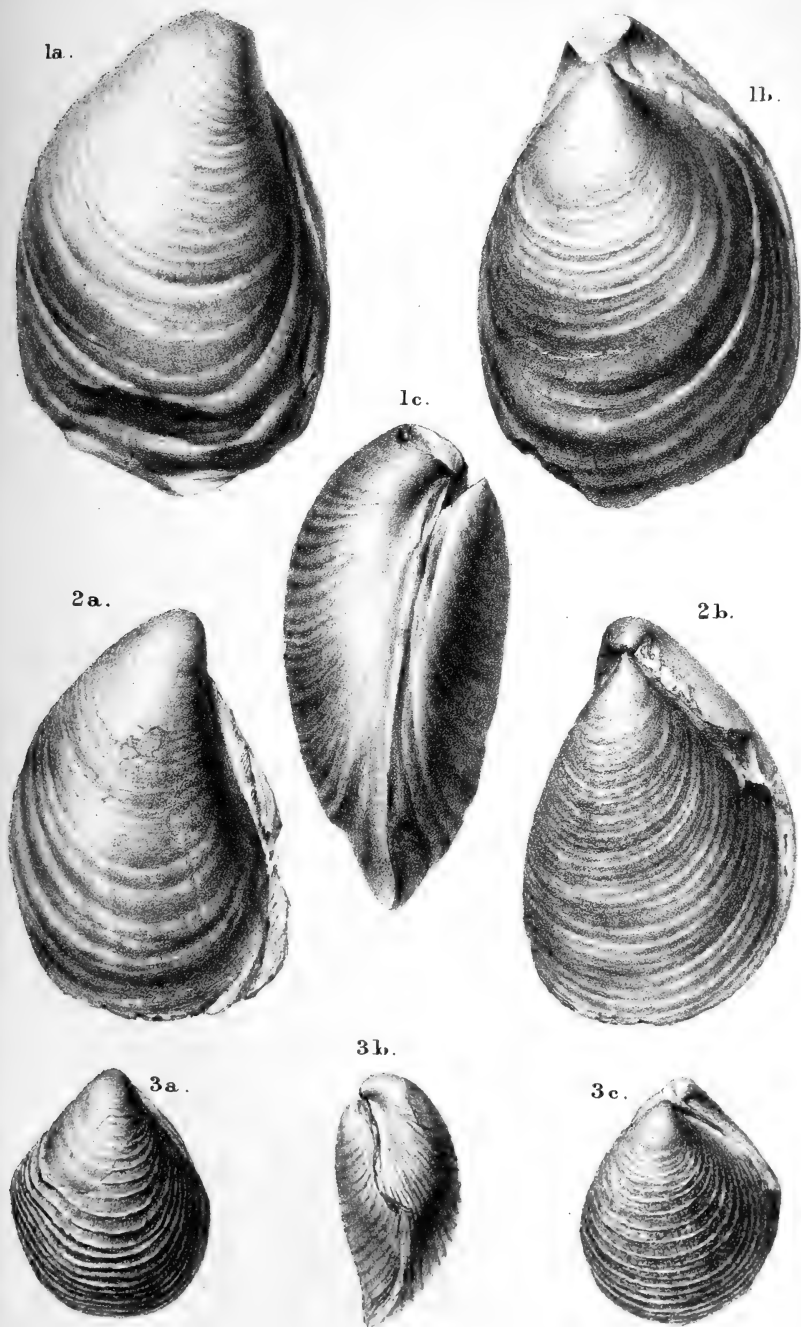
All the specimens are preserved in the Woodwardian Museum at Cambridge.

#### DISCUSSION.

Mr. STRAHAN remarked that this paper was of especial value at the present time, for English geologists had so far failed to establish a satisfactory separation of the Jurassic and Cretaceous systems. The correlation of the North of England with the South was still a matter of doubt, while even in the classic region which had furnished the names of Wealden, Purbeck, and Portland the upper limit of the Jurassic was quite uncertain. The Purbeck strata, first classed as Oolitic, were transferred by Webster and Fitton to the Wealden, reinstated as Oolitic by Forbes, and restored to the Wealden by Topley, while recently, seventy years after the question first arose, we have been assured by three different observers that the reptiles, fishes, and plants of the Wealden possess undeniable Oolitic affinities. Under such circumstances, a communication from a geologist of the world-wide experience of Prof. Pavlow promises to be of the utmost assistance to us in arriving at the most suitable grouping.

Mr. TEALL said that he was sure that all present regretted the absence of the Author. He could not discuss the paper, but he should like to give expression to the pleasure which he had felt in listening to it. Papers dealing with comparative stratigraphy of wide areas were rare at the Society, and he thought that the present one would therefore be cordially welcomed. He had not previously met with the terms 'hydrocratic' and 'geocratic,' but they seemed to him of great value. He had often felt the want of such terms.

Mr. LAMPLUGH expressed the extreme gratification that he felt at being made the medium for conveying this important paper to the Society. Whether the proposals of the Author with respect to the classification receive general acceptance or not, there could be no doubt of Prof. Pavlow's qualifications for the task, and the infinite





pains that he had taken in acquainting himself with the details of his subject in every part of Europe. It was entirely beyond the power of the speaker to discuss the broader bearings of the paper, and he could only approach it from a more or less insular standpoint. Moreover, certain criticisms which had suggested themselves to him when the paper first reached his hands, and which he had communicated to Prof. Pavlow, had been very satisfactorily answered by the Author in a letter which the speaker had before him. Yet he must admit that, before finally accepting as the division between the Jurassic and Cretaceous a line so locally inconvenient as that now proposed, which split the Spilsby Sandstone and the Zone D of Speeton, he preferred to await the result of further research. Not to speak of the uncertainty still existing in some parts of Europe, very little was at present known respecting the Infra-Cretaceous rocks of the Middle and South of England, and their relation to those found north of the Wash, and it was his hope that sooner or later he might be able to follow up the Lincolnshire work recently communicated to the Society by investigations farther south, where some elements of the Speeton fauna certainly existed. The recognition of the presence of the *Aucella* in Lincolnshire was important. He thought that similar fossils existed at Speeton, but in an inferior state of preservation. He believed that a careful study of the lamellibranchiata would bring out many other points of interest in the fauna in England.

33. GLACIAL DEPOSITS, PREGLACIAL VALLEYS, *and* INTERGLACIAL LAKE-FORMATIONS *in* SUBALPINE SWITZERLAND. By C. S. DU RICHE PRELLER, M.A., Ph.D., F.G.S., F.C.S., A.M.I.C.E., M.I.E.E. (Read March 11th, 1896.)

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## I. INTRODUCTION.

IN a paper which I had the honour of reading before the Society last session,<sup>1</sup> as well as in another previously published in the Geological Magazine,<sup>2</sup> I described in detail a variety of glacial deposits near the lakes of Constance, Zürich, Zug, and Thun, including several of those extensive and remarkable accumulations of glacio-fluviatile conglomerate which are the indirect product of land-ice and, together with intervening moraine and interglacial deposits, afford conclusive evidence of three separate and general glaciations not only of the Alps, but more or less of the Swiss lowlands.

The numerous sections of which I exhibited diagrams, revealed the apparently singular phenomenon that in the Zürich district the older glacio-fluviatile conglomerates generally crown the ridges of the Subalpine Molasse hills, and the younger gravel-beds occur at lower levels; while in the Lorze valley near Zug, and in the Kander valley near Thun, the position is reversed—that is, the older gravels, resting in the former locality on glacial clay and Molasse, and in the latter on glacial clay and Triassic beds, appear at the bottom, and are, with intermediate alternations of moraine, overlain by the younger series. From this marked contrast, it might be inferred that at the time of the deposition of the older gravels, the principal valleys in the last-named districts—that is, the basins of the Reuss and Aare,—were already eroded approximately to their present depth, whereas the Zürich valley was as yet non-existent or, at any rate, very imperfectly formed; so much so, that if this theory be correct, the oldest gravels, now commonly called Deckenschotter, must have been deposited as a sheet on a Molasse plateau extending practically from the present Zürich valley to that of the Rhine.

In the paper read last session, I alluded indeed, although merely

<sup>1</sup> Quart. Journ. Geol. Soc. vol. li. (1895) pp. 369 *et seqq.*

<sup>2</sup> Geol. Mag. 1894, pp. 27 *et seqq.*



by the way, to the occurrence of Cavernous Nagelfluh or Deckenschotter<sup>1</sup> in the Zürich valley itself, that is, at a considerably lower level than the Uetliberg and allied high-level deposits; and as the question involves the solution of an important problem, I took the opportunity of examining last summer a large additional number of glacial deposits throughout that district.<sup>2</sup> The object of this inquiry was twofold:—

(1) To ascertain which, if any, of the lower-level conglomerates must be regarded as the glacio-fluviatile products of the first or Upper Pliocene glaciation, or whether we must simply and *en bloc* accept the view recently enunciated by several Swiss geologists<sup>3</sup> that all the lower-level gravels are, without distinction, so-called Upper and Lower Terrace-gravels—that is, the indirect products of the two Pleistocene glaciations.

(2) To determine the probable and approximate depth of the Zürich valley before the deposition of the Deckenschotter—in other terms, to reconstruct the Preglacial valley as it appeared at the advent of the first glaciation in Upper Pliocene times. In the course of this enquiry, which has a direct bearing also on the general Preglacial configuration of the other principal Subalpine valleys, I was, moreover, led to several important conclusions with respect to the combination of causes which determined the formation of the lake of Zürich, and, in a wider sense, of the other lakes lying in the same zone at the foot of the Alps.

## II. CHARACTERISTICS AND ORIGIN OF CAVERNOUS NAGELFLUH OR SUBALPINE DECKENSCHOTTER.

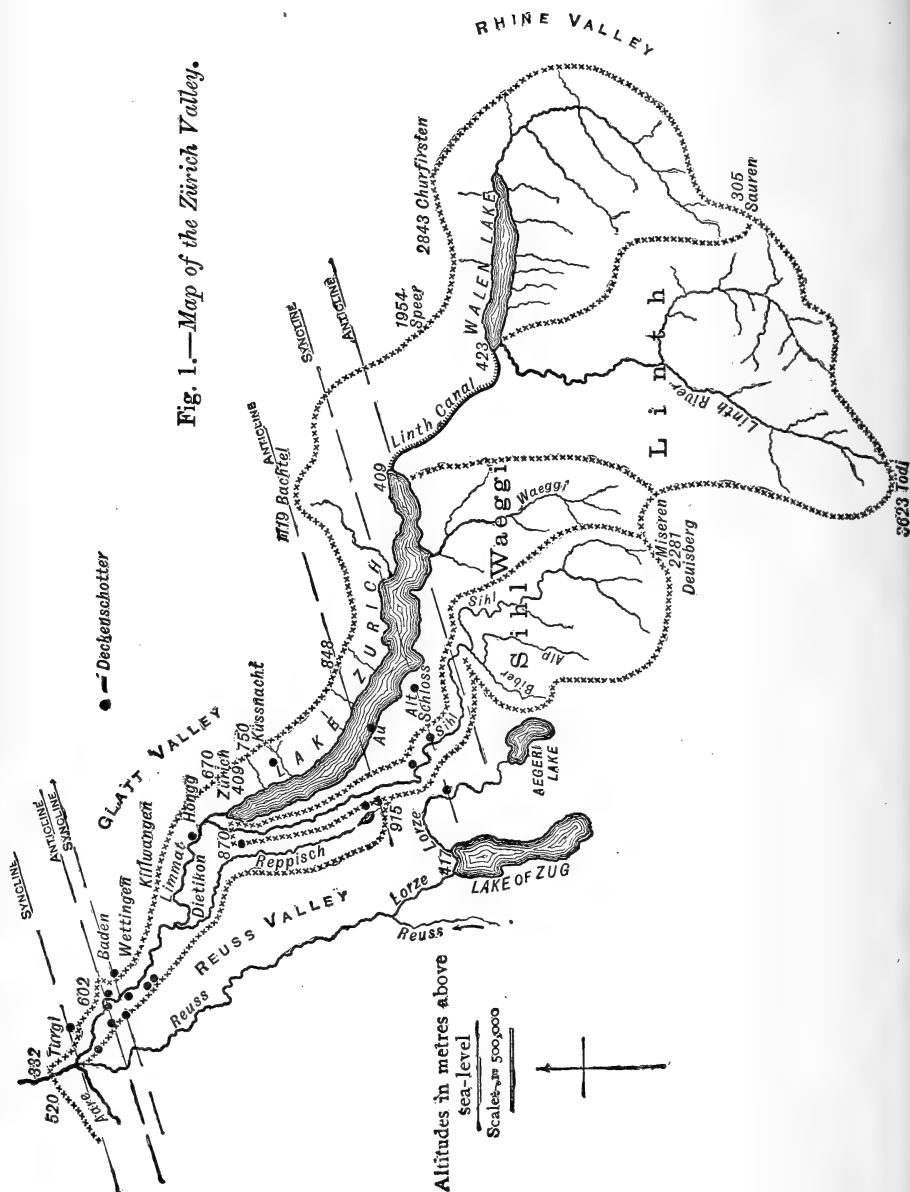
*Characteristics.*—The characteristics of the Subalpine Deckenschotter consist, according to my observations, chiefly in the occurrence of the conglomerate in isolated or continuous cliffs of peculiarly rugged appearance; in advanced cementation, not merely by siliceous material, but by calcification; in the occurrence of partially leached pebbles, and more especially of cavities left by pebbles which have been either wholly dissolved or have fallen out; in the generally noticeable stratification, as well as in the occurrence of underlying sand as a clear proof of the fluviatile origin of the deposit; and, lastly, in the occasional occurrence of striated pebbles as further proof that, in such cases, the deposit was formed at no great distance from a glacier.

<sup>1</sup> Although, as I shall show, the term 'Deckenschotter,' or plateau-gravel, is not strictly applicable to the Subalpine Cavernous Nagelfluh deposits, both terms are used throughout this paper as denoting the glacio-fluviatile conglomerate which is the indirect product of the first glaciation. The palæontological evidence of the Subalpine Deckenschotter having been deposited towards the end of the Pliocene period rests, as already pointed out in my paper of last session, mainly on the occurrence of *Mastodon arvernensis* in the analogous 'alluvions anciennes' of the Rhone valley above Lyons.

<sup>2</sup> Prof. T. G. Bonney, in his 'Ice-Work' (London, 1896), published since this paper was written, truly observes that the Zürich district is 'classic ground in the history of the work of ice.'

<sup>3</sup> Notably by Dr. L. Du Pasquier, Beiträge zur geol. Karte d. Schweiz, vol. xxxi. (1891), and by Dr. A. Aeppli, *ibid.* vol. xxxiv. (1894).

Fig. 1.—Map of the Zürich Valley.



Although these characteristics conspicuously distinguish the Deckenschotter from the older Miocene Nagelfluh, and—as regards the cliff-like appearance as well as the advanced calcification—also from the younger, Pleistocene gravels, the conglomerate varies greatly according to its position, to its derivation, and to the time of its deposition within the limits of the first Glacial period. And this is the more natural when we reflect how many must have been the glacial oscillations within that time, and that every advance of the glacier marks a stoppage, and every recession of the same marks a renewal of erosion at the terminal moraine. If, broadly speaking, we assume, in accordance with the general periodicity of Alpine glaciers of our own day, an alternate advance and recession of the glaciers of the first Ice-period every fifty years, there must have occurred in the space of, say, 5000 years, at least 100 semi-secular oscillations, during half of which glacio-fluviatile material must have been deposited in varying form, at various points, and at widely-varying levels.

*Origin.*—As I have already pointed out in previous papers, there is no room for doubt that the Deckenschotter of the Zürich district was, in the main, deposited by streams issuing from an extensive Linth glacier which, descending from the Glarner Alps, advanced to within a few miles of the lower Aare valley, and, together with the Rhine glacier on its right and the Sihl and Reuss glaciers on its left, formed, towards the end of the Pliocene period, one great Subalpine ice-sheet.

Although the moraine of these glaciers yielded part of the material of which the Deckenschotter was built up, the bulk of the conglomerate was not, in my opinion, transported by the glaciers from any great distance, but is derived from the enormous accumulations of Miocene Nagelfluh at the foot of the Alps. In this view I was confirmed by an examination of a large number of pits and natural sections of comparatively loose, both calcareous and polygène, Miocene Nagelfluh in the hills flanking the lake of Zürich.<sup>1</sup> This youngest Nagelfluh-zone, which corresponds to the Upper (freshwater) Molasse, extends longitudinally from the Lake of Constance to that of Thun and transversely as far as the Uetliberg near Zürich, and all the rocks occurring in the same are also largely represented in the Deckenschotter as well as in the younger, Pleistocene gravels; while the large boulders of Miocene Nagelfluh, which are occasionally found embedded in the Deckenschotter, are derived from the coarser and extremely hard conglomerate of the older, *i. e.* the Rigi, Rossberg, and Speer Nagelfluh-zones corresponding to the Lower (freshwater) Molasse.<sup>2</sup> Thus the successive deposition of Deckenschotter and Pleistocene gravels in three series, each of

<sup>1</sup> The pits and sections are those near Binz, Pfaffhausen, and Weilerhof in the hills on the right, and near Rüti and Wädenswil on the left of the Lake of Zürich.

<sup>2</sup> Strictly speaking, the Molasse and Miocene Nagelfluh formation comprises, besides the Lower freshwater, Marine, and Upper freshwater series, also the isolated Marine beds of the so-called Red (Oligocene) Molasse.

which was pushed farther out into the Subalpine valleys, resolves itself, in my view, mainly into a retransport, by glacio-fluvial agency, of Miocene fluvial material deposited in three mighty zones, one in front of the other, at the foot of the Alps.

### III. GLACIAL DEPOSITS.

In briefly describing the salient features of the various additional glacial deposits examined in the Zürich district, and extending over an area more than 40 miles in length, it will be convenient to begin at the lowest point, namely, at the confluence of the river Limmat with the Aare near Turgi, and thence proceed up the valley. The various deposits are marked in the map of the district (fig. 1, p. 558).

*Turgi*.—This locality is undoubtedly one of the most interesting in the Swiss lowlands, for it is here that the three principal rivers of Central Switzerland and main affluents of the Upper Rhine must have converged ever since Subalpine valleys were formed. As is shown in the sketch-map (fig. 2), there are high-level deposits of Deckenschotter at two points of the trough which marks the confluence of the three rivers—namely, on the two spurs called the Gebensdorfer Horn and the Siggenberg at the extreme end of the Limmat valley,<sup>1</sup> to the former of which I have already referred in a previous paper. These deposits are each about 60 metres in depth, very similar in character, and rest direct on Molasse without intervening moraine, the contact being on the Gebensdorfer Horn at contour 480 (metres), while on the Siggenberg it is at contour 550, or 70 metres higher. In the trough itself, where the mean river-level coincides with contour-line 330, the gravels deposited by the three rivers are so intermingled that it is extremely difficult to define their derivation, except that the Aare pebbles, having travelled a longer distance, are generally much smaller than those of the Reuss and the Limmat. At any rate, all the gravels at this point belong to the younger series, and, with the exception of some isolated blocks, the repeated powerful re-erosion at the junction of the three rivers has apparently left no vestige of Deckenschotter.

*Baden*.—The peculiar feature of this locality consists in a remarkable anticlinal Jurassic fold called the Laegern, which, traversing the Limmat valley almost at right angles, rises to 856 metres above sea-level, and towers fully 200 metres above the surrounding Molasse hills. In this saddle, a trough or basin with a steep, narrow, V-shaped passage for the river at each end, has been scooped out by fluvial action, and it is in this basin that several extremely interesting glacial sections are exposed.

As is seen from the sketch-map (fig. 2), the lowest of these sections occurs close to the edge on the left bank of the Limmat at contour 360, near the lower end of the basin, and a few hundred metres beyond the sharp bend of the river where the sulphur

<sup>1</sup> According to Dr. Du Pasquier (*op. cit.*), there is a cap of Deckenschotter also on the Bruggerberg, an isolated, oblong-shaped hill on the left bank of the Aare.

springs of Baden issue from fissures between the Keuper and the Liassic strata. The horizontally stratified conglomerate forms a cliff about  $\frac{1}{2}$  kilometre in length, and juts out at intervals from loose gravel and boulder-bearing moraine, which is banked up against it and fills the Baden basin to a depth of about 20 metres. A large artificial cave excavated in the conglomerate and a pit close by in the loose gravel and sand reveal a marked difference between the two deposits, the former being, in my view, a remnant of Cavernous Nagelfluh which escaped erosion, while the latter contains small lumps of the older conglomerate, and must therefore be the younger deposit of the two. The Nagelfluh, which is about 6 metres in depth, rests on about 1 metre of sand, and this again rests on marl and gypsum of the Keuper formation. At the side of a road above the cliff just mentioned, there is another remnant of the same conglomerate, and similar remnants are buried probably at other points of the Baden basin; at all events, several

others conspicuously project from the vineclad slope of the gravel- and moraine terrace between Baden and Turgi. This conglomerate exhibits all the characteristics of Deckenschotter and, in my opinion, must be regarded as such.

Another remarkable section of Deckenschotter occurs on the hill on the left side of the basin, near a point called Eichthal, close to a sharp bend of the high-level road from Baden to the Gebensdorfer Horn, and at contour 480. The exposure (fig. 3, p. 562), in which a large artificial cave has been excavated, exhibits an exceedingly hard, compact, irregularly stratified conglomerate about 6 metres in

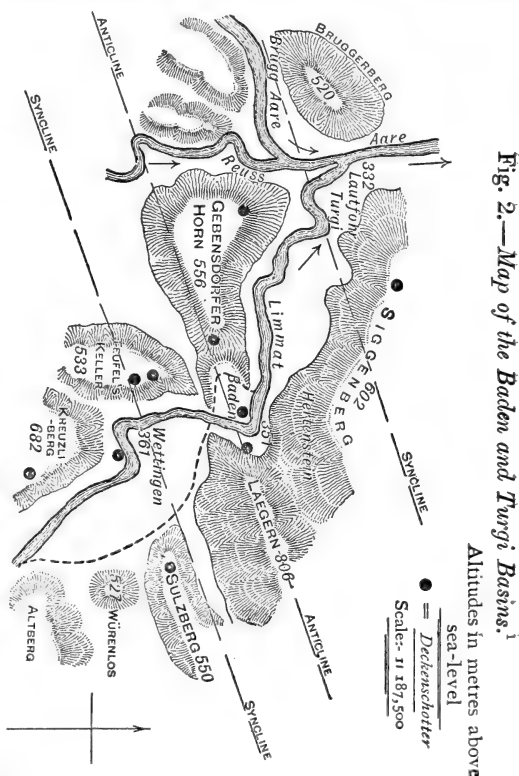
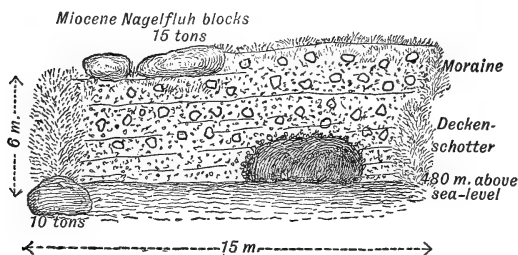


Fig. 2.—Map of the Baden and Turgi Basins.<sup>1</sup>

<sup>1</sup> For 'Lautföhr' in fig. 2 read 'Laufföhr.'

depth, mixed in its upper portion with boulders reaching the size of a man's head, and passing into about 2 metres of moraine, on which are stranded several enormous blocks of calcareous and polygène Miocene Nagelfluh, measuring about  $3 \times 2 \times 1$  metres, namely from 10 to 15 tons in weight. In its lower portion, the conglomerate shows irregular, somewhat oblique stratification, and numerous disintegrated pebbles, while many of the larger, often subangular pebbles, as well as the boulders in the upper portion, exhibit ice-scratches. This upward passage from glacio-fluviatile to purely glacial deposit therefore marks a period of transition, in other words, an oscillation of the glacier.

Fig. 3.—Section at Eichthal, near Baden.



Not less instructive, although of a more complex character, is an exposure on the opposite, that is, the Ennetbaden or right side of the basin, on the Ehrendingen road which skirts the slope of the Laegern. In this quarry, conspicuously situated at contour 412, or about 60 metres above the Limmat, is exposed a cliff of obviously very old, but, owing to disintegration, somewhat brittle conglomerate, about 15 metres in depth, banked up against the Jurassic strata, and containing in its upper portion a number of natural caves left by large well-rounded Miocene Nagelfluh boulders about 2 metres in diameter, which have gradually fallen down, and now encumber the floor of the quarry. The Nagelfluh is irregularly overlain and partially covered by morainic material mixed with Jurassic detritus, while in front of it—that is, in a pit excavated close to the road and at a lower level than the gravel floor—appears a younger, much more sandy conglomerate composed of much fresher pebbles. This later gravel, which was evidently banked up against the Deckenschotter cliff, reappears lower down the road and is excavated near the junction of roads at the upper end of the basin.

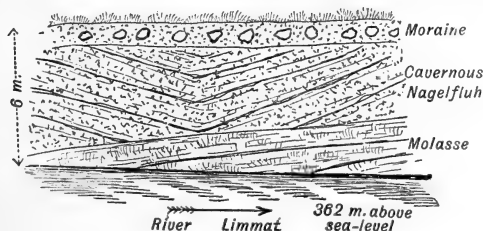
A fourth exposure examined in the Baden basin is that situated at contour 467, under the shelter of a Jurassic knoll called Guggenbühl, below the village of Hertenstein, near the lower end and on the right side of the basin. The two pits, facing each other, form part of a larger deposit and are excavated to a depth of about 5 metres; in both cases there are 3 metres of stratified, not very compact, conglomerate resting on about 1 metre of sand and

passing in its upper, coarser portion, into 1 metre of morainic material. The transition-zone contains numerous striated pebbles and boulders, and, as is universally the case in Alpine glacial deposits, it is the dark grey limestone which takes ice-scratches and impressions of all kinds more readily than any other rock. The conglomerate is scarcely hard enough to be genuine Deckenschotter, and contains, moreover, small lumps of the latter. Hence it must be regarded as being the product, not of the first, but of the second glaciation. At any rate, the deposit clearly marks a glacial oscillation, and it is on this account that it is of special interest.

Even putting aside the last-named, somewhat doubtful, deposit, we have thus in the Baden basin distinct and conclusive evidence of Deckenschotter at three different levels—that is, close to the river at contour 360, and on the slopes of the hills at each side of the basin, at contours 480 and 412 respectively.

*Wettingen.*—The next important occurrence is about 3 kilometres above Baden, near the Convent of Wettingen above the sharp curve described by the Limmat, which is here crossed by two railway viaducts. Beginning under the upper viaduct at contour 370, a cliff of very compact conglomerate about 6 metres in depth runs for a distance of a few hundred metres up the river along the left bank, jutting out at intervals from the younger gravel and overlying moraine. Exactly under the viaduct and about 10 metres from the left abutment, the Molasse, which here appears about 2 metres above the river-level, has a slight but distinct dip up the valley, while the Nagelfluh cliff which directly overlies it dips in the opposite direction (fig. 4). The vineclad slope of the opposite bank of the

Fig. 4.—Section at Wettingen, near the Upper Viaduct.



river, composed of loose gravel and moraine, is likewise marked by several projecting remnants of the same conglomerate, in conspicuous contrast to the loose gravel, which, in a pit reaching down to the river's edge, is irregularly overlain by moraine. The occurrence at Wettingen therefore presents features precisely analogous to that of Baden: the phenomenon of the younger deposits covering and being banked up against the old conglomerate is manifest in both cases. To the left of the Convent of Wettingen lies the Deckenschotter deposit of Teufelskeller, already

described in previous papers, and on the right side a small cap of the same conglomerate on an isolated hill called the Sulzberg. Thus the Deckenschotter appears at three points across the valley, the contact with Molasse being at the two extremes approximately at contours 470 and 480, and in the valley at contour 362.

Between the Teufelskeller deposit near Baden and that of the Uetliberg near Zürich, several ledges of Deckenschotter occur on the upper slope of the broad Molasse ridges locally called Heitersberg and Hasenberg, the conglomerate being overlain by moraine of the second glaciation to a depth varying from 50 to 100 metres, while the opposite or Altberg ridge, between Sulzberg and Zürich, has apparently been entirely denuded of all evidence of the first glaciation, even the younger moraine overlying the Molasse being of insignificant thickness as compared with that on the ridge of the left side of the valley.

*Killwangen and Würenlos.*—Returning now to the Limmat valley and proceeding from Wettingen upward, we come, at a distance of about 4 kilometres, to the remarkable moraine-wall of Killwangen, which I described in an earlier paper as marking the limit of the third glaciation. Near the village of Würenlos, on the right side of the valley, there is, in a large and conspicuously situated sandstone quarry, a very striking and clean-cut exposure of moraine overlying the Marine Molasse to a depth of 6 metres. The moraine, in which are embedded large boulders of Miocene Nagelfluh and Sernifite, shows that the glacier travelled over the Molasse without in the slightest degree disturbing the latter, much less eroding it. This moraine deposit, occurring, as it does, at least 1 kilometre in advance of the terminal moraine of Killwangen, must, in my opinion, be regarded as belonging to the second and not to the third glaciation.

*Limmat Gravel-beds.*—The Killwangen moraine-wall rests on the so-called 'Limmat gravel,' which is the fluvatile product of the second glaciation. Dr. Du Pasquier has been led to regard all the valley-gravel and overlying moraine below Killwangen and as far as Turgi as the product of the third glaciation: that is, as constituting the glacia or 'Gletscherboden' of the Linth glacier of that Ice-period. It is, perhaps, somewhat hazardous thus to draw a hard-and-fast line between the two Pleistocene gravels in the Limmat valley. The glacier of the third Ice-period, after stopping at, and receding from, Killwangen, remained probably for a long time stationary at the lower end of the present Lake of Zürich, as is evidenced by the belt of moraine-walls so characteristic of that city. On Dr. Du Pasquier's theory, it would therefore follow that all the gravel-beds between Zürich and Killwangen were deposited during that second stoppage, and are consequently the product of the youngest or third glaciation, whereas they undoubtedly belong to the older Pleistocene series, since the Killwangen moraine-wall distinctly overlies them. The material derived from the Zürich and Killwangen moraine must therefore have been deposited on the older gravel and moraine, and was by subsequent denudation in



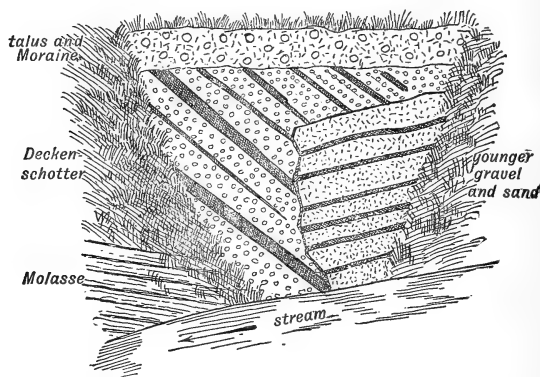
great part or entirely removed, and carried beyond Turgi into the Aare and Rhine valleys. On these grounds, the whole of the younger gravels as well as the overlying thin coating of moraine in the lower Limmat valley must, in my opinion, be regarded as, in the main, the product of second glaciation, and as having probably been deposited during the recession of the Linth glacier of that period. The cliffs and other remnants *in situ* of old conglomerate projecting from that gravel and moraine, and embedded in the valley at Baden and Wettingen, afford conclusive proof that, at the time of the deposition of that old conglomerate, the floor of the valley was already in existence. The great difference of level between the Cavernous Nagelfluh or Deckenschotter deposits on the ridges of the Molasse hills and those at the bottom of the valley seem, at first sight, to point to subsequent erosion on an enormous scale; but, in my view, the high-level deposits were formed during the maximum extension of the Upper Pliocene Subalpine ice-sheet, which, filling the valley and spreading over the hills on both sides, probably reached to the lower end of the Baden basin, while the low-level deposits were formed during the recession of the glacier when the latter had already shrunk considerably, and was itself embedded in the valley.

*Höngg*.—About 11 kilometres from Killwangen, on the right side of the valley, below the village of Höngg, and close to the road, a conspicuous exposure or cliff of Cavernous Nagelfluh partially excavated occurs at contour 420, about 30 metres above the present river-level. The well-cemented, but coarse, indistinctly stratified conglomerate, about 7 metres in depth, rests on sand, and is overlain by about 2 metres of moraine and talus. The presence of numerous scratched pebbles shows that it was deposited not far from the glacier, but the overlying moraine, which has left it entirely undisturbed, is a younger deposit, probably of the third glaciation. The conglomerate must, in my view, be regarded as Deckenschotter, and this is confirmed by a pit about 100 metres lower down on the same road, where a much looser younger gravel, interstratified with sand and overlain by moraine, is exposed. The phenomenon already noticed at Wettingen and Baden, of younger gravel being banked up against a remnant of older conglomerate, is, therefore, observable also at Höngg, the younger gravel being, like the extensive gravel-beds at the bottom of the valley, the product of the second glaciation.

*Küssnacht*.—Passing over the typical Deckenschotter deposit of the Uetliberg, as well as the more recent deposits in the immediate vicinity of Zürich already described in previous papers, the next locality of interest is on the right shore of the lake, about 5 kilometres above Zürich, in the Küssnacht ravine, deeply eroded in glacial deposit and Molasse by the torrent or Tobel of the same name. In the upper part of this ravine, about 4 kilometres from the lake, several cliffs of Cavernous Nagelfluh crop out from the moraine by which the Molasse is covered to a depth of 50 to 100 metres. At one point on the left bank of the torrent, and at contour 520, one of

these cliffs is accessible, the section here exposed being shown in the diagram, fig. 5. The extremely compact, but in some parts

Fig. 5.—Section in the Küssnacht Ravine.



disintegrated and brittle conglomerate, about 20 metres in depth, dips up the valley at an angle of no less than 40 degrees, and against it are banked, at its upper end, several alternations, each about 1 metre in depth, of younger stratified sand and gravel dipping in the opposite direction. In a small pit, a few hundred metres farther up the ravine and at about the same level, there appears, in superposed layers of 2 metres each, fresh sand and gravel overlain by moraine with large boulders, this deposit being evidently part of the same deposit as the younger sand and gravel in the other exposure. The moraine which overlies the gravel in both these exposures exhibits the irregular, mound- and knoll-shaped contours so characteristic of the moraine of the third glaciation. The contact of the Cavernous Nagelfluh with the Molasse, near the edge of the torrent, is buried under gravel detritus, although the Molasse appears immediately below and above the deposit; but at a short distance higher up the ravine, the torrent, whose bed is throughout encumbered with erratic blocks of occasionally enormous size,<sup>1</sup> flows no longer on Molasse but on glacial clay, an additional proof of the great age of the upper part of this valley. The Molasse strata in the lower part show a gentle but very distinct dip up the ravine; it would, however, be hazardous to infer that the steep reverse dip of the Cavernous Nagelfluh is the result of the same displacement by earth-movements. At all events, the various phenomena described warrant the conclusion that that conglomerate can only be Deckenschotter, while the gravel banked up against it is the product of the second glaciation.

<sup>1</sup> The largest of these erratic blocks in the Küssnacht ravine is, according to my measurements,  $3 \times 3 \times 3$  metres, equal to 60 tons in weight, and bears the name of 'Alexanderstein,' in memory of the late Dr. Alexander Wettstein, who described the Küssnacht ravine in his 'Geologie von Zürich, etc.,' 1885, and a few years later lost his life on the Jungfrau.

*Au*.—About 9 kilometres from Küsnacht, but on the left side of the lake and close to the shore, is situated the peninsula of *Au*, entirely composed of glacio-fluviatile gravel, the origin and the age of which have long been a fruitful source of discussion. Escher von der Linth and others regarded it as of Tertiary age and contemporaneous with the Uetliberg Nagelfluh—that is, pre-Glacial—in the old acceptance of the term; while latterly, among others by Dr. Aeppli,<sup>1</sup> it has been classed with the Low Terrace, namely, the Pleistocene gravels of the third glaciation. In the paper read last session, I mentioned it incidentally as probably being a detritus-cone deposited by the river Sihl during the older Pleistocene or second Interglacial period, but a close examination of the locality has led me to modify this view. The peninsula (fig. 6) forms an oblong dome-shaped cone rather less than 1 kilometre in length and about 50 metres in depth, the summit being at contour 456, while the mean lake-level is at contour 409. All along the edge of the lake-level, but more especially at the western end, and facing the lake, there appears a cliff with both natural and artificial caves, of



hard, compact, and irregularly stratified conglomerate from 5 to 15 metres in depth, many of whose pebbles, varying in size up to that of a man's fist, are leached and disintegrated and show traces of former crushing and other impressions. In one exposure, where the stratification is clearly marked, a stratum of sand 5 metres thick is intercalated between the Cavernous Nagelfluh, and the whole deposit has a dip up the valley of about 20°, which is, however, due simply to its deposition as a detritus-cone, and not to earth-movements. At another point the Cavernous Nagelfluh is covered by a looser and coarser gravel, largely composed of rough and very imperfectly rolled pebbles of Sernifite, evidently deposited subsequently and by a stream flowing transversely over the conglomerate into the lake. In a farm-shed near the summit of the peninsula, at contour 445, one of the walls, 12×4 metres, is formed by gravel also dipping up the valley and composed, in upward succession, of 1 metre of sand containing pebbles, 2 metres of very coarse and loosely cemented gravel in which are embedded boulders up to 1 metre in diameter, and 1 metre of loose, somewhat less coarse gravel. This is obviously, like the Sernifite-bearing gravel lower down, a much younger deposit than the conglomerate of the cliff bordering the edge of the lake, the latter being, in my

<sup>1</sup> Beiträge z. geol. Karte d. Schweiz, vol. xxxiv. (1894) p. 94.

view, Deckenschotter, while the former, which constitutes the upper portion of the peninsula, is probably the indirect product of the second glaciation. The contact of the old conglomerate with the Molasse is not disclosed, but is probably some 20 metres below the level of the lake, which near this point attains its maximum depth of about 142 metres. The occurrence of Deckenschotter on this quasi-promontory, and even below the lake-level, is, at first sight, extremely puzzling; but the phenomenon admits, in my opinion, of an adequate explanation, namely, that the submerged Molasse-floor of the present peninsula was originally, that is, before the first glaciation, at a higher level; that on this Molasse-floor the Deckenschotter was deposited during the recession of the glacier; that during the following Interglacial period it was, by erosion, reduced to an island which shared the general subsidence of that part of the valley, as I shall show farther on; that the superposed younger gravel, which also filled the gap between the island and the mainland, was deposited during the recession of the glacier of the second Ice-period, and that the gap was re-eroded after the third glaciation, the island thus reconstituted being, by subsequent alluvial deposit, again connected with the mainland, and assuming the form of a peninsula, as it appears at the present day.

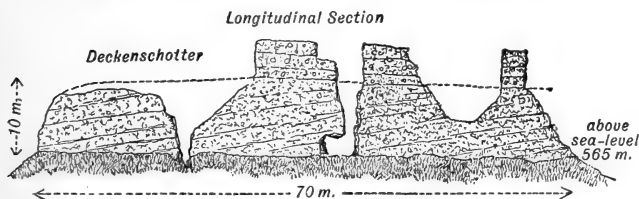
*Albishorn.*—On the Albis range, which flanks the left side of the Zürich lake- and Sihl valleys, and extends from the Uetliberg to the Albishorn, the Molasse is generally overlain by moraine and an abundance of erratic blocks of the second or maximum glaciation; but above and below this moraine there occur, more especially near the southern end, various deposits of glacio-fluvial conglomerate, of which those of the Albishorn and Bürglenstutz may serve as typical examples. Below the inn on the summit of the Albishorn, which is at contour 915, or 45 metres higher than the summit of the Uetliberg, a spring issues at the contact of the Deckenschotter and the underlying impervious, boulder-bearing, glacial clay. The latter can be traced some distance down the brook, but its contact with the Molasse is indistinct and lies somewhere near contour 850. The cliff of well-cemented, coarse, and horizontally stratified Cavernous Nagelfluh which overlies the glacial clay is about 5 metres in depth. The pebbles, occasionally striated and coarser at the top than at the bottom, are, however, remarkably fresh, and the conglomerate, although obviously Deckenschotter, differs from the Uetliberg deposit just as much as the latter differs from that of Au, in striking confirmation of my former conclusion that the difference observable between various deposits of this conglomerate is not of kind, but of degree. Upon the Albishorn Deckenschotter rests, to a depth of about 15 metres, a much looser conglomerate, in which scratched pebbles, as evidence of the proximity of the glacier, are numerous, and which, moreover, contains small lumps of the old conglomerate; while farther on, towards the end of the range, the same gravel overlies an extensive exposure of loose surface-moraine about 20 metres in depth. On both sides of the Albishorn inn the Deckenschotter crops out at various points of the narrow ridge,

from the gravel and moraine-detritus under which it is generally buried. We have, therefore, at the Albishorn clear evidence of Deckenschotter, which, even at this high level, is overlain by moraine and gravel of a younger glaciation.

This is strikingly confirmed by an even more instructive exposure near the summit of the Bürglenstutz, which latter is situated about 2 kilometres from the Albishorn towards the Uetliberg, and, being at contour 918, is the highest point of the Albis range. The Molasse appears here near contour 850, or practically at the same level as on the Uetliberg and Albishorn, and is overlain by about 25 metres of horizontally stratified, typical Deckenschotter, upon which follows glacial clay and moraine to a depth of about 15 metres; and this, in its turn, is overlain by about 25 metres of much looser and irregularly stratified gravel, which closely resembles the upper gravel on the Albishorn.

*Altschloss.*—One of the most remarkable deposits of Deckenschotter is that of Altschloss, on the hills above Wädenswil on the left side of, and about 1 kilometre from the lake, and near the Burghalden station of the Wädenswil, Einsiedeln, and Goldau railway. The exposure, which is shown in the diagram (fig. 7) in longitudinal section, consists of three separate, originally connected cliffs of extremely hard conglomerate, and the cliffs are crowned by the ruins of the feudal castle of Altschloss, built, like the surrounding wall and a bridge, entirely of this conglomerate. The identity of

Fig. 7.—Section at Altschloss, near Wädenswil.

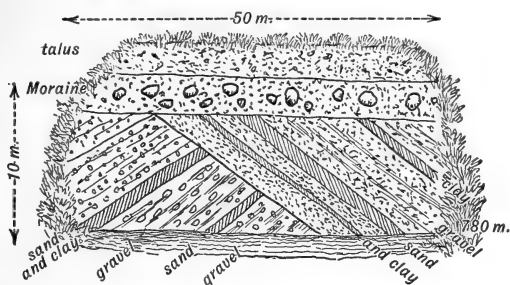


colour and the almost imperceptible passage from the natural to the artificial structure produce the exceedingly striking effect of the whole being one solid mass, and the perfect preservation of the dressed blocks about 1 metre square attests the even more than usual hardness of the conglomerate. The cliffs are about 10 metres in height, and one of them contains a large cave, where sand appears at the bottom of the horizontally stratified conglomerate. The cliffs form part of a larger deposit which extends also to, and crowns, the neighbouring hill of Gehren, and to the orphan asylum above Wädenswil, as is evidenced by several cliff-like outcrops. The contact of the Deckenschotter with the Molasse is obliterated by detritus, talus, and vegetation; but several springs which collect the water at the bottom of the conglomerate show the contact to be at about contour 550, while the summit of the Altschloss cliffs is at contour 570. In my view, the Altschloss deposit shares with



original bed, which lay probably in the direction indicated in the sketch-map by a dotted line (fig. 8). Of this, proof is afforded by a remarkable exposure at Kaltboden, on the left bank of the present Sihl, about 1 kilometre above Schindelleggi, close to the railway and road leading to Einsiedeln. As is shown in the diagram (fig. 9),

Fig. 9.—Section at Kaltboden, near Schindelleggi.

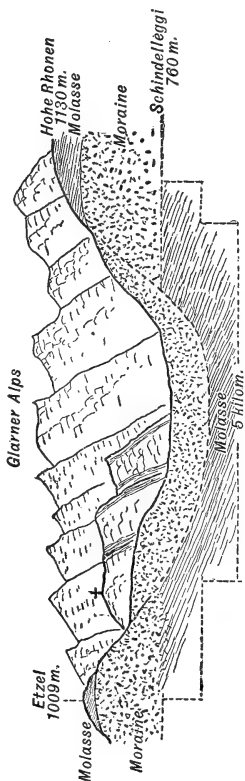


the section exposed in the large pit at contour 320, about 10 metres in depth, consists in its lower part of alternating layers of fine gravel, sand, and clay, dipping in opposite directions, and overlain by 3 metres of moraine followed by 2 metres of talus. With the exception of a little adventitious Sernifite, the gravel is mainly composed of yellow and grey limestone- and sandstone-pebbles, upon which no ice-scratches are observable, while the moraine contains striated boulders from the size of a man's head to 1 metre in diameter, both the calcareous and polygène Miocene Nagelfluh being largely represented. Below this pit, and on the same slope, along a canal running parallel to the river at contour 775, another large quarry, recently opened, exhibits a horizontally stratified section, 20 metres in depth, composed of 7 metres of glacial clay and 10 metres of sand and gravel, overlain by 3 metres of moraine and talus. The moraine at the top of the upper as well as of the lower quarry is of the third, the clay at the bottom of the lower quarry is of the second glaciation; hence we have in the lower and upper exposure an extensive Interglacial, that is, strictly fluvial delta and superposed detritus-cone deposited by the Sihl after the second Ice-period. The floor of the detritus-cone is probably not much below that of the upper quarry, as is evidenced by a spring which issues a few hundred metres higher up the road at contour 824. The extent of these deposits, no less than the beautifully clean-cut sections, the typical detritus-cone structure, and, in addition, the absolute flatness of the overlying moraine, showing the total absence of any ploughing action of the glacier, combine to render the two exposures of Kaltboden among the most striking and instructive of the whole district.

Before the deposition of the Kaltboden delta, and, *à fortiori*, immediately before the advent of the first glaciation, the course of the Sihl must have been at a lower level, namely, on Molasse. That

the original outlet of that river was to the Zürich valley is evidenced by the deep and broad depression eroded between the two mountain-spurs of Etzel and Hohe Rhonen, near Kaltboden, as is shown in the diagram (fig. 10). The ratio of slope of the two mountains places

Fig. 10.—Molasse-depression and moraine-wall between Etzel and Hohe Rhonen, 350 metres above Lake Zürich.



the Preglacial Molasse-bed of the river somewhat to the east of the Kaltboden exposure, that is, near Geissboden, where a sharp reverse curve of the Sihl marks the first point of deflection, just below the present confluence of the Sihl and Alp. The Molasse-bed would here probably be at contour 700—that is, about 80 metres below the present moraine-bed of the river, and no less than 120 metres below the crest of the moraine-wall, which now bars the old outlet. From here to the then floor of the Zürich valley the river, flowing in the direction of the present bay of Richterswil, must have formed a rapid, having a fall of about 7 per cent. (1 in 13), through a narrow V-shaped valley or ravine, which is now deeply buried under moraine, and probably resembled closely the Molasse ravine of the present river-course between Schindelleggi and Sihlbrugg.

A second point of deflection of the Sihl from the Zürich basin occurs at Schindelleggi at contour 750, where the river describes a sharp curve at an angle of 50°. The entrance of the deep ravine at this point, just below the railway-bridge, is shown in the

transverse section (fig. 11), and presents the peculiar feature that the left bank is formed by a wall of Lower (freshwater, so-called raised) Molasse, and the right bank by a moraine-wall 50 metres in depth, resting, however, on Molasse, as is evidenced by a sandstone quarry. This moraine-wall, which contains, besides angular blocks, enormous boulders of Miocene Nagelfluh up to 3 metres in diameter, and shows irregular, but yet distinct divisional lines, marking the superposition of younger on older moraine of successive glaciations, is a continuation of the wall at the upper point of deflection near Geissboden, and constitutes the bar thrown across the Preglacial outlet by the Linth glacier, which thus deflected the Sihl and its successive glaciers to the Reuss basin, until that river eroded its present bed parallel to, but outside the drainage-area of the Lake of Zürich. It is hardly necessary to mention that the Sihl glacier-torrent which



deposited the Deckenschotter of the Menzingen plateau and Lorze valley, already described in a previous paper,<sup>1</sup> must have flowed at a much higher level, that is, probably 150 metres higher than the Molasse-bed of the Preglacial Sihl near Geissboden, or that of the present Sihl at Schindelleggi.

In the foregoing description of glacial deposits I claim to have shown: (1) that deposits and remnants *in situ* of Deckenschotter occur not only on or near the ridge of the hills, but also at the bottom and on the slopes flanking the Zürich valley, notably at Baden, Wettingen, Höngg, Küsnacht, Au, and Altschloss, of which the first four deposits appear respectively at a gradually ascending level, while the last two are now at a lower level than they were at the time of their deposition; (2) that in the first four cases referred to, younger glacio-fluviatile gravel, in the main the product of the second glaciation, is banked up against the old conglomerate, and that in several cases, for example, at Baden and Wettingen, the old conglomerate resting on Molasse, is buried under the younger gravel, which, in its turn, is overlain by moraine.

These phenomena lead to the conclusion that at the time immediately preceding the deposition of the Deckenschotter—in other terms, at the advent of the first glaciation, towards the end of the Pliocene period—the Zürich valley was already eroded, the depth of the lower part of the valley being approximately that which it has at the present day, while the floor of the upper part of the valley was at a higher level than that of the present lake, and, as I shall show in the sequel, was subsequently lowered by a subsidence due to earth-movements.

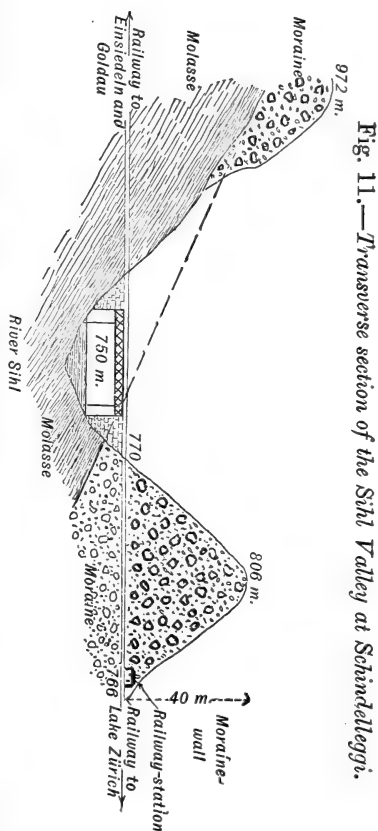


Fig. 11.—Transverse section of the Sihl Valley at Schindelleggi.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. li. (1895) pp. 369 *et seqq.*

## IV. PREGLACIAL SUBALPINE VALLEYS.

I have already shown in an earlier part of this paper that, so far as the ice-sheet which covered the Swiss lowlands towards the end of the Pliocene period can be subdivided, the Linth glacier was, in the main, confined to the Zürich valley, while an arm of the Rhine glacier spread even then over the Glatt district north of the Zürich basin. The same applies, in my opinion, to the flow of the two rivers before the first glaciation—in other words, the Glatt valley, now practically dried up, was originally eroded by an arm of the Rhine,<sup>1</sup> and the Zürich valley by the Linth jointly with the Sihl, whose original, but subsequently barred outlet to the Zürich basin lay, as already stated, in a line from Schindelleggi to the present bay of Richterswil.

The erosion of the Zürich basin as a continuous valley from the upper end of the present lake to Turgi involved the removal of two saddles; one, the Jurassic Laegern bar at Baden, and the other the Molasse and Miocene Nagelfluh saddle which stretched across from near Richterswil to Rapperswil, as is evidenced by the two low islands of Ufenau and Lützelau, which now form a reef obliquely across the upper end of the present lake, the Marine Molasse and Miocene Nagelfluh rising just above lake-level. The Baden bar must have been, in the first instance, sawn through by the backward erosion of a torrent descending from the Laegern towards the basin of the Aare, until it was sufficiently lowered to admit the Linth, which subsequently completed the erosion of the lower valley. The erosion of the Laegern bar must necessarily have preceded the first glaciation, because, if it were otherwise, the Deckenschotter deposit of the Gebensdorfer Horn, situated north of the Laegern, could not be the glacio-fluvial product of the Linth glacier. As regards the Ufenau saddle, the process was probably precisely similar to that at Baden: that is, the torrent originally descending from it towards the Zürich basin, and sawing the saddle by backward erosion, was subsequently superseded by the Linth. On the other hand, unlike

<sup>1</sup> The theory that the Glatt valley was originally eroded by the Linth, and the Zürich valley by the Sihl, has been advocated by Wettstein and by Prof. Heim ('*Geologie v. Zürich*,' 1885, and *Neujahrsschrift Naturf. Ges. Zürich*, 1891), while Dr. Du Pasquier (*Beiträge*, vol. xxxi. 1891, p. 122) favours the presumption that even the Rhine Valley, from the Irschel hills to the confluence of the Aare near Waldshut, was originally eroded by the Linth. In my view, these two rivers are much too small to have eroded such broad valleys. The drainage-areas of the Sihl, Linth, and Rhine at Schindelleggi, Walen Lake, and Sargans respectively, are about 200 : 600 : 4200 sq. kilom., and, at a rainfall of 2 metres per annum, less 25 per cent. for absorption, yield respectively 10, 30, and 210 cubic metres per second, the proportion being, therefore, 1 : 3 : 21. If we assume that one-third of the volume of the Rhine was deflected at Sargans to the west (while the main arm flowed N.N.W. through the Constance basin, and thence towards the Danube until deflected to the W. towards Schaffhausen), we have an adequate flow for the erosion of the present Walen Lake fjord, the Glatt valley, and the Rhine Valley from Irschel to Waldshut by the western arm of the ancient Rhine, and a sufficient volume for the erosion of the Zürich valley by the combined Linth and Sihl.

the narrow Baden defile, which, near the apex of the two V-shaped passages, is even now not more than 30 metres in width, the valley at the lake-level near Ufenau is at least 3 kilometres broad, and hence the removal of the old saddle cannot be attributed solely to the erosive action of the Preglacial Linth, but must be, in part, the effect of a subsequent subsidence of the old valley-floor, as will appear in the sequel.

Proceeding now to the reconstruction of the Zürich valley (figs. 1 & 12, pp. 558, 577) as it appeared at the advent of the first glaciation, we have to trace the lowest points at which the solid rock appears, as marking the old valley-floor, especially where the rock is directly overlain by Deckenschotter.

Beginning at the confluence of the Limmat and Aare, near Turgi, we find the solid rock practically at river-level on the left bank of the Aare at Lauffohr, exactly at the junction, that is at contour 332. Thence proceeding up the Limmat valley, we strike it again for about a hundred metres at the river-level about halfway between Turgi and Baden, at contour 340; then at Baden, near the lower end of the basin, at contour 351; and again at Wettingen, near the lower and upper viaducts, at contours 358 and 362 respectively, both the Lower Baden and Upper Wettingen exposures being, as already shown, directly overlain by Cavernous Nagelfluh. The first section of the old valley-floor thus has a fall of 30 metres in 8·5 kilometres, or 3·5 metres per 1000, equal to 1 in 286, or roughly 1 in 300. If we assume this as the uniform fall also for the upper sections, the old valley-floor was near Hôngg at contour 412, a few metres lower than the Deckenschotter exposure described, and about 15 metres above the present river-level; near Zürich at contour 433, or 24 metres higher than the present lake; near Küsnacht at contour 451, or 42 metres higher than the lake, and about 50 metres lower than the Deckenschotter deposit in the Küsnacht ravine; near Au at contour 483, or 74 metres above the present lake-level; near Altschloss at contour 500, or 91 metres higher; and near Richterswil—that is, on a level with the Marine Molasse bank of Wollerau—at contour 518, or 109 metres above the present lake-level, the distance of this point from Turgi being 52 kilometres. The Marine Molasse bank of Wollerau, at contour 518, marks the confluence of the Preglacial Linth and Sihl, and therefore approximately also the then level of the passage already eroded in the Ufenau saddle, whose highest points, namely, Ufenau and Lützelau, must, however, have been as yet at a higher level. If, proceeding from this point upwards, we assume the gradient of the Preglacial Linth valley to be the same as in the lower sections, the floor at the junction of the Linth and western Rhine valleys near Wesen, or the present Walen Lake (distance 25 kilometres), must have been at contour 605, or 182 metres above the present level of that lake, while at Glarus, or 10 kilometres farther, it was at contour 640, that is, 159 metres higher than the present valley-floor at that point. The same gradient prolonged from Wesen for a distance of 30 kilometres through the Walen lake-basin to Sargans, the point

of bifurcation of the two arms of the Preglacial Rhine,<sup>1</sup> would place the valley-floor at that point at contour 710, or 190 metres higher than the present valley. As regards the Sihl valley, its Preglacial course from the old confluence with the Linth near Wollerau to Schindelleggi and upward has already been dealt with in a preceding part of this paper.

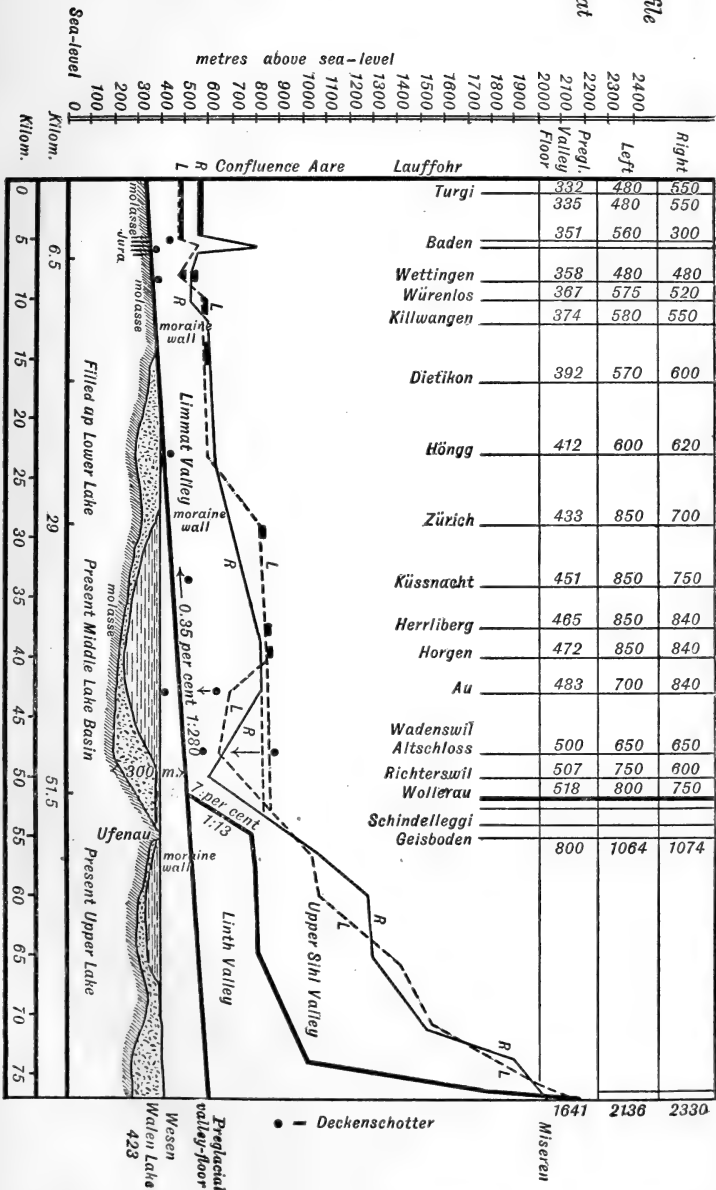
In the profile (fig. 12), plotted from the various altitudes given in the preceding paragraph, I have inserted at their respective levels the different low-level occurrences of Deckenschotter in the Zürich valley between Turgi and the junction of the Preglacial Linth and Sihl, near the old Ufenau bar. From the contours already given, it is seen that the inclination of the ancient valley-floor is by no means arbitrarily chosen, but corresponds more or less closely to the gradually ascending level of those Deckenschotter exposures, that is, to their contact with the underlying solid rock, except the deposits of Au and Altschloss, which, as already mentioned, lie in a zone of subsequent subsidence. Moreover, having regard to the meandering and irregular course of the river, the fall of 3·5 per kilometre of the valley-floor corresponds to only about half, that is, to 1·75 kilometre, or about 1 in 600 of the river, whose mean velocity, in a shallow section of about 200 square metres, would not exceed  $\frac{1}{2}$  metre per second, or about 1 mile per hour. At this velocity the erosion on the convex side of one bend of the river would be approximately balanced by re-deposition of material on the concave side of the next. Under these conditions the Linth, immediately before the first glaciation, must have been essentially a sluggish river, the more so as its course was not regulated as it is at the present day. Of such ancient windings the Zürich valley offers numerous examples, one of the most striking of which occurs at Wettingen and Baden, where the river has repeatedly changed from one side of the valley to the other, the present curved course being the exact reverse of a former one, which I have indicated by a dotted line in the sketch-map (fig. 2, p. 561).<sup>2</sup>

In the profile (fig. 12) of the Preglacial valley-floor, I have further plotted (of course, only diagrammatically) the salient points of the Molasse crest-line on both sides of the valley. This crest-line, having been in many places buried under successive glacial deposits, which were in part again removed by subsequent denudation, has not, since the advent of the Ice-age, undergone any very marked changes as regards its general elevation, and therefore enables us, in conjunction with the old valley-floor, to determine the con-

<sup>1</sup> The low alluvial saddle near Sargans, which now separates the Rhine from the Walen lake-basin, is only 5 metres in depth and about 5 kilom. in width. In the year 1817 the Rhine nearly overflowed again into the Walen lake-basin. In order to meet this contingency, the railway along that lake to Sargans and Ragatz was not allowed to cross the bar by a cutting, but had to pass over it.

<sup>2</sup> Similar changes in the river-course were, no doubt, produced also in Glacial times, when, during a recession of the glacier, the glacier-stream was banked by the terminal moraine-wall, until it overflowed the latter at the lowest point or effected a breach at the point of least resistance.

Fig. 12.—Profile  
of the Zürich  
Valley (Limmat  
and Linth).



figuration and depth of the Preglacial valley by transverse sections. Of such transverse sections I have plotted no less than twenty, from which I have deduced a mean section for each of the three divisions of the Zürich valley, covering in the aggregate a distance of over 50 kilometres, as follows:—

	kilometres.
(1) Turgi (confluence of the Limmat and Aare) and Baden.....	6·5
(2) Baden (upper end of basin) and Zürich end of present lake...	22·5
(3) Zürich and Wollerau, or Ufenau bar (Preglacial confluence of Linth and Sihl) .....	22·5
	<hr/> 51·5

Again, from these divisional mean sections I have deduced a general mean section, both the former and latter being shown in the diagrams (figs. 13, 14, 15, & 16), and drawn to an uniform horizontal and vertical scale. As is seen, the old valley widens and deepens gradually from its lower to its upper end, and the general mean section gives a width between the crest-lines of about 7 kilometres and a depth of 300 metres,<sup>1</sup> the general ratio of slope being 5°, equal to 8·7 per cent., or 1 in 11·5, while the vertical dip, or proportion of depth and upper width, is 1 : 23, and the cross-section of the valley therefore represents an extremely flat curve.

If we compare this valley with two contiguous old valleys—namely, that of the Glatt, eroded by an ancient arm of the Rhine, and that of the Reuss—we find that they all present the flat dome-shaped ridges and the correspondingly shallow depressions which are eminently characteristic of all Molasse valleys eroded by large rivers. The Albis or Uetliberg range, dividing the Zürich and Reuss basins, is the only one whose Preglacial dome-shaped configuration has been profoundly altered by the Postglacial erosion of its right flank by the Sihl, and of its left flank by the Reppisch, in consequence of which the original dome was converted into a  $\Lambda$  (inverted wedge-shaped) central ridge, with a low ridge on each side.

<sup>1</sup> The totals of the calculation are as follows, the sections being considered as flat parabolas, according to the formula  $\frac{2}{3} sh$ .

	Upper width. <i>s</i> metres.		Depth. <i>h</i> metres.		Length. metres.		Cubic contents. cubic metres.
I.	$\frac{2}{3} \times 2210$	$\times$	157	$\times$	6500	=	1503 million.
II.	$\frac{2}{3} \times 4820$	$\times$	191	$\times$	22500	=	13809 „
III.	$\frac{2}{3} \times 9700$	$\times$	400	$\times$	22500	=	58199 „
					<hr/> 51500		<hr/> 73511 „

Hence the mean section is 1,427,000 sq. m., the mean width 6·6 kilom., and the mean depth 323 m. In round figures, the total quantity of material removed by erosion for about 50 kilom. may therefore be taken at 70,000 million cubic metres, the mean section at 1,400,000 sq. m., and the mean width and depth at 7 kilom. and 300 m. respectively.

It is on the ancient flat and broad ridge which, at the advent of the Ice-age, extended continuously from the Albishorn to the Uetliberg, Baden, and the Gebensdorfer Horn,<sup>1</sup> that the various deposits of old conglomerate were formed during the first glaciation: and seeing that they occur at irregular intervals, each of them marks, in my view, a stage in the general but intermittent recession of the ice-sheet. As regards the evidence of the Preglacial floor of the lower Aare valley, whose course along the foot of the Jura lies, moreover, in a natural synclinal channel between that range

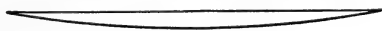
#### TRANSVERSE SECTIONS OF THE ZÜRICH VALLEY.

Fig. 13.—*Lauffohr to Baden.*



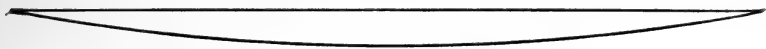
[Width=2.21 kilom.; depth=157 metres.]

Fig. 14.—*Baden to Zürich.*



[Width=4.82 kilom.; depth=191 metres.]

Fig. 15.—*Zürich to Ufenau.*



[Width=9.7 kilom.; depth=400 metres.]

Fig. 16.—*Mean transverse section.*



[Width=7 kilom.; depth=300 metres.]

Scale=1 : 100,000.

and the Subalpine Molasse, I have traced the solid rock close to the river's edge at Brugg, near the confluence with the Reuss, as well as at Lauffohr, as already mentioned, while, according to Dr. Du Pasquier, it also appears in many places above Brugg, as well as at several points between Lauffohr and the confluence of the Aare and Rhine.

Again, in the last-named valley, both below and above that confluence, long stretches of solid rock at river-level are mentioned by the same writer, who is himself led to the conclusion that this valley was already formed before the first glaciation, the Decken-

<sup>1</sup> Various small transverse valleys and depressions were, during subsequent interglacial periods and in Postglacial times, formed in this ridge by erosion and landslips; it is, therefore, no longer continuous at the present day.

schotter being embedded in the valley.<sup>1</sup> A further striking example is that of the Rhone valley, which Prof. F. A. Forel, in his well-known work on the Lake of Geneva, conclusively shows to be post-Miocene, but pre-Pleistocene<sup>2</sup>—that is, of Pliocene and Preglacial age.

There is thus abundant evidence that all the principal river-valleys of Subalpine Switzerland were, in the main, already formed and excavated before the advent of the first glaciation.<sup>3</sup>

## V. THE ORIGIN OF SUBALPINE LAKE-BASINS.

From the profile of the Preglacial valley-floor, it is evident that at the advent of the first glaciation the Lake of Zürich had not yet come into existence. That its formation is primarily due to a subsidence of the old valley-floor is attested, not only by the great and unknown depth at which the solid rock lies buried beneath moraine and gravel near the outflow of the river Limmat from the Lake of Zürich, where borings have failed to reach the Molasse even at 40 metres below the river-bed, but by the gradually increasing depth of the lake from Zürich upwards, the deepest point, about halfway, and not far from Au, being 142 metres below lake-level, although even here the bottom consists not of solid rock, but of mud and other lake-deposit overlying the same. From this point the lake, much filled with moraine and sand, again rapidly decreases in depth as far as the old Ufenau bar, where the Molasse appears at lake-level; and immediately beyond—that is, on the other side of the bridge—emerges the old moraine-wall which banked the upper or shallow lake-basin, the Molasse being in this basin again covered to a great depth by glacial and other deposits. As already shown, the solid rock appears at the confluence of the Limmat and Aare, near Turgi, at contour 332, and again near Wettingen, at contours 358 and 362, while the deepest point of the lake lies at contour 266, or 66 and 94 metres lower than the solid rock near Turgi and Wettingen respectively. This remarkable difference of level clearly points to a subsidence of the old valley-floor for a distance, measured longitudinally, of nearly 40 kilometres.

On examining the profile (p. 577), it will be observed that the general crest-line of the hills flanking the Zürich valley is marked by two distinct anticlines trending obliquely across the valley and parallel to the general strike of the Jura and Alps, namely, the

<sup>1</sup> Beiträge z. geol. Karte d. Schweiz, vol. xxxi. (1891) p. 103. In another place (p. 106) Dr. Du Pasquier states that the transverse valleys (*e.g.* the Aare Valley), too, must have been already, though imperfectly, formed even in Miocene times, as is shown by the occurrence of Miocene Nagelfluh.

<sup>2</sup> 'Le Léman,' vol. i. (1892) p. 240.

<sup>3</sup> I have not dealt in this paper with the Eastern Alps; but there is no doubt that the Inn Valley above and below Innsbruck is also Preglacial, the old gravels being deeply embedded in it. This view is also shared by Dr. Du Pasquier, *op. jam cit.* p. 106.



Jurassic Laegern anticline at Baden, and the anticline of the Albishorn, which trends across the lake between Horgen and Au. The first of these was obviously formed in Miocene times, that is, before the first glaciation, and the same applies therefore to the small synclinal folds of the Gebensdorfer Horn and Teufelskeller, lying respectively on the northern and southern flanks of the Laegern fold. If these synclinal folds were of later, that is, Glacial age, the Deckenschotter deposits would show conclusive traces of having shared the displacement of the underlying strata; but, on the contrary, that conglomerate rests in almost every instance unconformably on the Molasse. Thus, on the Gebensdorfer Horn it overlies horizontally the Molasse, which dips north at an angle of about  $20^\circ$ ; at Teufelskeller, in the quarry on the northern slope of the hill, the stratification is likewise perfectly horizontal, while the slight reverse dip of only about  $4^\circ$  at one or two points of the southern cliff is more apparent than real, and therefore so doubtful that any inference drawn from it is devoid of value. Again, at Wettingen, where the Molasse at river-level has a gentle inclination up the valley, the Nagelfluh overlying it near the upper viaduct clearly dips in the opposite direction, and on the Uetliberg, too, as well as on the Albis range generally, the superposition is distinctly unconformable. In face of this evidence, it is clear that all the principal earth-movements in the lower part of the Zürich valley took place before the first Ice-period, and not after the deposition of the Deckenschotter.

Essentially different, however, is the case of the second or Horgen anticline in the upper part of the valley. From Horgen to Au and Wädenswil, for a distance of about 6 kilometres and on both sides of the lake, the Molasse-terraces of erosion exhibit a distinct reverse dip, which I have also verified in the hills above Au, namely, in the ravine of a stream descending parallel to the lake, from Rüti to Wädenswil, where the Molasse bank is overlain by Miocene Nagelfluh. The reverse dip of the terraces of erosion bordering the lake was first pointed out by Prof. Heim<sup>1</sup>; and although the inclination does not exceed 2 per cent. on an angle of about  $1^\circ$ , and is, indeed, according to my observations, of an undulating rather than uniform character, the phenomenon is yet of unquestionable importance, the more so as the maximum dip of the terraces down the valley is only 0.9 per cent., that is, about  $0.5^\circ$ , or  $\frac{1}{10}$  of the ordinary ratio of slope of the hills towards the lake. Even more decisive proof of a considerable zonal subsidence, extending from that part of the Lake of Zürich across the so-called Hirzel and Menzingen plateau to the Lake of Zug, is afforded by the greatly disturbed Molasse strata in the Sihl valley, notably about 1 kilometre above Sihlbrugg, where, close to a sharp bend of the Hirzel road at contour 550, I have verified a dip up the valley of the Molasse of no less than  $25^\circ$ . Other distinctly reverse inclinations of the Molasse occur in the Sihl ravine near Sihlsprung and in

<sup>1</sup> Beiträge z. geol. Karte d. Schweiz, vol. xxv. (1891) p. 476.

the Lorze ravine north of the stalactite-caves, the dip up the valley being in these two cases about  $1^{\circ}$ . It is important to note that not only at the two points just mentioned, but also at Altschloss, the contact of the Molasse underlying the Deckenschotter is near contour 550; that the reverse dip (*i. e.*  $1^{\circ}$ ) of the terraces of erosion bordering the Lake of Zürich is approximately the same as that in the Sihl and Lorze ravines; and, lastly, that the two points noticed in those ravines lie, together with Altschloss, in a line parallel to the strike of the Alps. In other words, this line marks the syncline of the subsidence-zone, and it is to this subsidence that the Lake of Zürich primarily owes its origin.

As regards the Deckenschotter deposits, the evidence of reverse dips on and near the Albishorn—indeed, as I have already shown, of the high-level occurrences generally—is either doubtful, inconclusive, or directly negative; and the same applies to the lower-level deposits of Au and Altschloss, as well as to those in the Lorze and Sihl ravines. The apparent or occasional slight dip of these deposits, either in one direction or the other, is, in my view, due simply to their character of detritus-cones, with the exception of one case on the Hirzel road near the village of Oberkellenholz, where, at contour 647, a cliff of Deckenschotter, crossing that road at right angles, drops, according to my measurements, at an angle of  $2\frac{1}{2}^{\circ}$  for some distance towards the Sihl ravine. Having regard to the general reverse dip of the Molasse in this region, varying from  $1^{\circ}$  to  $5^{\circ}$  and  $25^{\circ}$ , the inclination of the Deckenschotter cliff just noticed warrants the inference that the zonal subsidence between the Lake of Zürich and that of Zug, and with it the formation of the Zürich lake-basin, took place after the deposition of that conglomerate, probably between the first and second glaciations, and at any rate in Pleistocene times.

The approximate depth of this subsidence may be determined from the difference of level between the anticline near the Albishorn and the syncline already referred to. Although the Molasse strata of the Albis range have, in places, a dip of as much as  $1\frac{1}{2}^{\circ}$  down the valley, the crest-line of the rock, irregularly overlain by glacial deposits, is practically horizontal, since at both ends, that is, at the Uetliberg and near the Albishorn, and also midway, the solid rock appears near contour 850. The difference of level between the Molasse at the Albishorn and that at the three synclinal points is 300 metres, and this is therefore the approximate maximum depth of subsidence of the zone between the lakes of Zürich and Zug, and hence also of the old Zürich valley.<sup>1</sup>

If the irregularly-shaped glacial deposits, under which the Molasse of the Hirzel and Menzingen plateau is now buried, could

<sup>1</sup> By an elaborate calculation, Dr. Aeppli (Beiträge, vol. xxxiv. pp. 75, 76) arrives at a subsidence of 425 metres, his computation being based, not upon the contact-points of the solid rock (obviously the only reliable standard), but upon the summit-levels of the Deckenschotter deposits, which latter may, however, have undergone many changes since they were formed. Wettstein ('Geol. Zürich,' p. 57) and Dr. Du Pasquier (Beiträge, vol. xxxi. p. 116) arrived at about

be removed, the configuration of the subsidence-zone between the two lakes would be that of a flat dome-shaped ridge which, before the subsidence, was a continuation of the original Albis range, and, being then 300 metres higher, was practically at the same altitude as the Molasse of the latter—that is, approximately at contour 850. It is therefore on this old plateau that the Altschloss Deckenschotter, now 300 metres lower, was deposited, while that of Au, assuming it to extend 20 metres below present lake-level (to contour 390), was deposited at an altitude 207 metres higher, that is, approximately at contour 660, or on the upper slope of the old ridge.

As is seen from the profile, the Preglacial valley-floor near Altschloss was at contour 500 and, after the subsidence of 300 metres, at contour 200. The lowest point of the present lake-bed, composed of lake-deposit, is at contour 266; but the solid rock probably lies 15 metres lower, namely at contour 251. A line drawn from contour 200 through contour 251 and thence prolonged, strikes the Preglacial valley-floor at contour 374—that is, near Killwangen, about 17 kilometres below the end of the present lake at Zürich. Killwangen therefore marks the probable starting-point of the subsidence of the Preglacial valley-floor, and consequently the probable lower end of the original lake-basin.

The formation of the lake-basin kept pace with the gradual subsidence of the valley-floor, and was therefore very slow; that is, the river becoming gradually more sluggish, formed pools, and, finally, a continuous sheet of water with an outlet at the lower end. The deposit of the second, and, again, of the third glaciation gradually filled the lower basin, and subsequently a Postglacial bar, deposited by the Sihl at its inflow into the Limmat just below Zürich, defined the present limits of the lake at its lower end.

The phenomenon of similar Postglacial bars is traceable also in other Subalpine lake-formations. Thus, the Rhine which formed the Lake of Constance, was probably, in the first instance, barred by the Danube, and subsequently deflected by moraine-walls towards Schaffhausen; the Walen Lake, originally connected with the Lake of Zürich, was barred by the Linth; the Lake of Zug by the Lorze, and probably also by the Reuss; the Lake of Lucerne by the Emme, although here the evidence is not so clear; the Lake of Brienz, originally connected with that of Thun, was banked by the delta of the Lütschinen, while the Lake of Thun was banked by the Kander; again, the Aare banked the Lakes of Neuchâtel and Bienne, and the bar deposited by the Arve at its inflow into the Rhone was largely instrumental in forcing the Lake of Geneva back to its present limits. Similarly, in Savoy, the Lake of Annecy was barred by the Fier, and the Lac

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142 and 160 metres as the depth of the subsidence, their calculation being, however, based simply upon the difference of level between the Molasse near Baden and the deepest point of the lake, *plus* the fall of the present valley-floor, or 0·17 in 100.

du Bourget by the Rhone.<sup>1</sup> In all these cases, then, a delta and superposed detritus-cone were thrown across the lake-valley practically at right angles, and thus the four successive main phases in the formation of Subalpine lakes of our own day may be summed up as follows:—fluvial erosion of the Preglacial valleys; subsidence of the valley-floors in their upper parts by unequal earth-movements in the Alps; partial filling of the original lake-basins by glacial and glacio-fluvial deposit at both ends; and, finally, restriction of the lower ends of the lakes to their present limits by fluvial Post-glacial bars.

## VI. CONCLUSION.

It will be observed that the conclusions at which I have arrived in this paper differ in some respects widely from the views recently enunciated by several Swiss geologists. More especially does this difference relate to the question whether the principal Subalpine valleys were excavated before or after the first or Upper Pliocene glaciation.

Apart from the evidence I have adduced, my conclusion that the first glaciation found the principal Subalpine valleys already eroded derives substantial support from the very history of the Tertiary epoch. In Eocene times the Alps had already emerged from the surrounding sea, though as yet only as a group of low islands. The Miocene period witnessed the principal thrusting and folding of the Jura and the Alps; and the products of increased denudation—namely, sand and clay, afterwards hardened to Molasse, and fluvial detritus subsequently cemented to compact conglomerate—were deposited between the two ranges in two freshwater and one intermediate marine series, the latter being formed in an arm of the sea which, towards the end of the Miocene period, still reached from the Mayence basin to the foot of the Alps. The process of folding continuing, the Subalpine Molasse and the enormous banks of conglomerate, too, were raised, notably near the Alps; the sea receded; the lakes formed in the shallow depressions of the Molasse plateau dried up, and, consequent upon the increased steepness of the Alpine slopes, denudation and erosion set in on a greatly enhanced scale; rapids and ravines formed; the great Alpine rivers effected in the Miocene Nagelfluh walls those breaches which later on afforded easy and convenient passages to glaciers; and broad valleys were eroded in the soft Molasse strata of the Swiss lowlands, the general direction of discharge being towards the natural collecting-channel along the foot of the Jura, and thence to the Rhine. Thus, the Lower and Middle Pliocene period in Subalpine Switzerland did not witness the deposition of any new rock-formations, but

<sup>1</sup> Prof. F. A. Forel (*op. cit.* p. 246) is disposed to regard even the alluvium of the River Po as having been instrumental in forming the contour of the Italian lakes at their lower ends; but the formation of these southern lake-basins is a much more complex question than that of the lakes at the northern base of the Alps, and I have refrained from dealing with them in this paper, as they are outside its immediate scope.

was an unbroken period of erosion and denudation on a prodigious scale. The long duration of this post-Miocene and pre-Glacial period appears the more obvious when we reflect that it was contemporaneous with the formation of the extensive marine beds of the Subapennine hills and of Sicily.

It is a singular fact that the geological epoch which immediately preceded the appearance of man is perhaps the most difficult to unravel. But unless we assume that in this post-Miocene and pre-Glacial period, which Sir Charles Lyell regarded as of incalculable duration,<sup>1</sup> the work of Nature stood still, we are driven to the conclusion that, at the advent of the first Ice-period in Upper Pliocene times, the principal Subalpine valleys were already excavated approximately to their present depth, and that ever since then the action of the great Alpine and Subalpine rivers has been, as it still is in our own day, mainly directed to regaining the old valley-floors by removing those enormous accumulations of glacial and glacio-fluviatile material which are respectively the direct and indirect products of three successive and general glaciations.

#### DISCUSSION.

Prof. BONNEY said that he had been shown some of the sections described by Dr. Preller, and could answer for the relations of the various gravels and moraines. He felt some doubts as to the occurrence of 'Deckenschotter' by the side of the Limmat below Baden. He felt the greatest difficulty of all in understanding how the Deckenschotter was deposited on the Uetliberg and yet could occur by the Lake, for that meant a difference of at least 1200 feet, and he saw no way of explaining this. Was the valley filled up with loose débris, or had it been deepened? Which hypothesis offered the less difficulty?

The Rev. EDWIN HILL spoke of the great interest of the subject, especially the singular alterations in the courses of rivers. Like moraine-formed tarns, we had now shown to us moraine-diverted rivers.

Dr. G. J. HINDE enquired of the Author if there were any palæontological grounds for attributing a Pliocene age to the plateau fluvio-glacial gravels or 'Deckenschotter.' The well-known fact of the similarity of the constituents of the gravels and conglomerates, both of those of the plateau and of the high and low terraces, must make discrimination difficult; and he doubted the value of the evidence relied on by the Author to prove that certain gravels and conglomerates close to Zürich and nearly at the level of the Lake belonged to the same period as the 'Deckenschotter' at the top of the Uetliberg, nearly 1500 feet higher.

The AUTHOR thanked the various speakers for their remarks. In

<sup>1</sup> 'Antiquity of Man,' 1863, p. 316. Sir Charles Lyell speaks of the 'countless post-Miocene ages which preceded the Glacial Epoch,' and in which 'there was ample time for the slow erosion by water of all the principal hydrographical basins of the Alps.'

reply to Prof. Bonney he observed (1) that, as explained in the paper, the high-level Pliocene Nagelfluh-deposits were, in his view, formed during the recession of the ice-sheet, and the low-level deposits during the subsequent recession of the local glaciers left in the valleys; (2) that hence it was by no means necessary to assume the Zürich Valley to have been filled with that glacio-fluviatile material to a depth of 1200 feet—indeed, the individual deposits probably in no case exceeded 200 feet in depth; (3) that he had found distinct evidence of younger, loose gravel being banked against the older calcified conglomerate both at various points near Baden and elsewhere; and (4) that the Uetliberg conglomerate was not deposited on the present narrow ridge, but on a flat Molasse dome which afforded ample room for a glacier-stream, and whose flanks were subsequently excavated and sapped by a parallel Postglacial river on each side. In reply to Dr. Hinde, he said that he used the term 'Pliocene' Nagelfluh (1) because the conglomerate was clearly younger than the Miocene conglomerate and older than the Pleistocene gravels; and (2) because the first glaciation, including the deposition of the conglomerate in question, was by Swiss geologists, too, explicitly and on grounds of palæontological analogy, referred to the Upper Pliocene period. With regard to Mr. Hill's remarks, he regarded the deflection of the Sihl, from its original outlet to the Lake of Zürich, by a stupendous moraine-wall 5 miles in length and 400 feet in depth, as one of the most remarkable instances of its kind in the Swiss Alps.

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## EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

### SESSION 1896-97.

1896.

Wednesday, November .....	4-18
"      December .....	2-16

1897.

"      January .....	6-20
"      February ( <i>Anniversary</i> , Feb. 19) .....	3-24
"      March .....	10-24
"      April .....	7-28
"      May .....	12-26
"      June .....	9-23

[*Business will commence at Eight o'Clock precisely each Evening.*]

34. *The KILDARE INLIER.* By S. H. REYNOLDS, Esq., M.A., F.G.S., and C. I. GARDINER, Esq., M.A., F.G.S. (Read May 27th, 1896.)

## [PLATE XXVIII.]

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## I. INTRODUCTION.

THE Geological Survey of Ireland, in 1858, published a memoir describing the geology of the Kildare Hills and neighbouring country. In this memoir are given lists of fossils from the limestone and from an underlying ash-bed, attention is drawn to the resemblance which some of the igneous rocks bear to those of Lambay Island, and reference is made to the presence of a north-and-south fault dividing the inlier into two portions.

In 1877 Messrs. Harkness and Nicholson,<sup>1</sup> in their paper on 'the Strata between the Borrowdale Series and Coniston Flags,' give some account of the Kildare rocks. They mention that the limestone is in the direct line of strike of contemporaneous beds at Portrairie, near Dublin, and also of the Coniston Limestone of the Lake District. Moreover they judge from the strike of the Kildare limestone that it is faulted against the rocks east of it, and note that the beds west of the north-and-south fault above mentioned are entirely dissimilar to those lying east of it.

The area has been repeatedly referred to by Mr. J. E. Marr<sup>2</sup> in his various papers on the Coniston Limestone Series of the Lake District. In them he draws special attention to the resemblance between the Keisley Limestone and that of the Chair of Kildare.

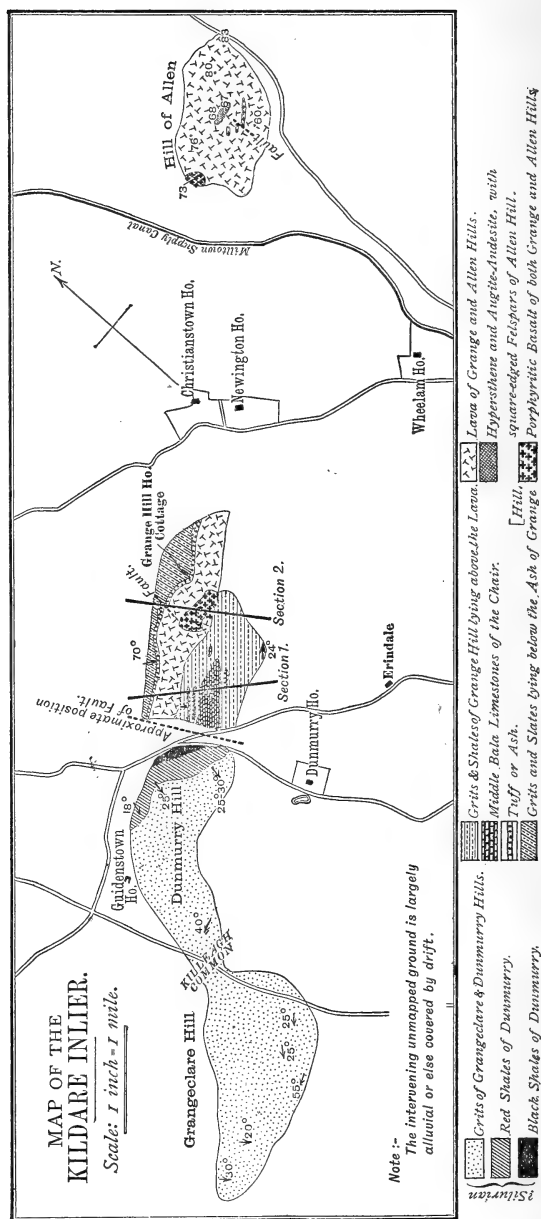
## II. GENERAL DESCRIPTION OF THE AREA.

The Carboniferous Limestone to the south-west of Dublin has been thrown into a series of gentle undulations, and to the north and north-west of the town of Kildare the crest of one of these undulations has been denuded away, exposing a strip of pre-Carboniferous rocks. The inlier thus formed is some 6 miles long,

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxiii. (1877) p. 481.

<sup>2</sup> Geol. Mag. 1892, pp. 97 *et seqq.*

Fig. 1.



Note.—For 'Dunmurry' in explanation of map, read 'Dunmurry Hill.'

and on the average about  $\frac{3}{4}$  mile broad. In this small area there are exposed rocks of Ordovician and probably also of Silurian age, while red micaceous sandstones and quartzose conglomerates, referred by the officers of the Geological Survey to the Old Red Sandstone Series, protrude in places from beneath the Carboniferous Limestone, and rest on the upturned edges of the older rocks.

The area is easily noted from a distance, as it is formed of four prominent hills arranged in a line running roughly in a north-east and south-west direction, and rising some 400 to 450 feet above the level of the surrounding country. Of these four hills, that farthest to the south-west is Grange Clare Hill, then comes Dunmurry Hill, then Grange Hill with the Chair of Kildare as a projection, while finally to the north-east lies the Hill of Allen. The whole of the surrounding country is deeply covered with drift, the junction of the Carboniferous Limestone and Old Red Sandstone with the beds of the inlier being never seen.

We shall describe first the sedimentary and afterwards the igneous rocks; and since the stratigraphical succession is best seen on Grange Hill we shall first describe that hill, including with it the Chair.

The complete absence of cliff or stream-sections has rendered the correlation of the beds a matter of some difficulty.

### III. THE SEDIMENTARY ROCKS OF GRANGE HILL AND THE CHAIR OF KILDARE.

The lowest beds are seen on the northern slopes of Grange Hill. They consist of olive-green gritty shales dipping south-east at an angle of from  $60^{\circ}$  to  $70^{\circ}$ . Associated with them are some more definitely gritty bands which pass occasionally into a conglomerate containing well-rounded pebbles of shale and grit, often some  $\frac{3}{4}$  inch in length. These gritty shales pass up into an andesitic ash which can be traced all along the foot of the hill to a point north-north-west of the top of the Chair. This ash has proved very fossiliferous just behind Grange Hill House Cottage, where it is exposed some 10 feet below the base of the overlying igneous rock, under which it dips to the south-east at an angle of about  $60^{\circ}$ . At this point, moreover, it is of a distinctly more gritty type than elsewhere.

From this ash we obtained the following fossils:—

*Pinacopora Grayæ*, Nich. & Eth.

*Orthis porcata*, M'Coy

— *alternata*, Sow.

— *flabellulum*, Sow. (very common)

— *calligramma*, Sow.

— *testudinaria*, Sow.

*Strophomena deltoidea*, Conrad

— *expansa*, Sow. (common)

*Leptæna* (*Plectambonites*) *sericea*, Sow.

*Calymene senaria*, Conrad (very common)

*Calymene Blumenbachii*, Brongn.

*Ctenodonta varicosa*, Sow. (very common)

*Orthonota parallela*, Hall

*Modiolopsis expansa*, Portl.

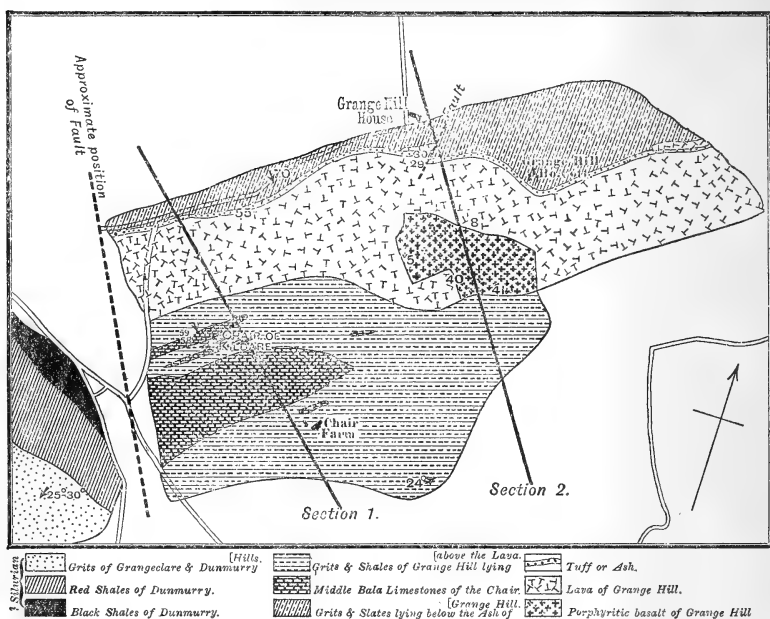
*Raphistoma æqualis*, Salt. (very common)

*Holopella*, sp.

*Murchisonia sulcata*, M'Coy

*Pleurotomaria* cf. *claustrata*, Lindstr.

Fig. 2.—Map of the Central portion of the Kildare Inlier.



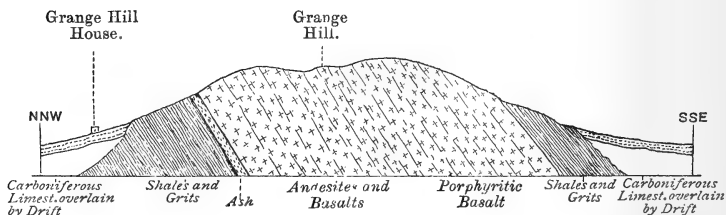
[Scale : 3 inches = 1 mile.]

*Note.*—The numbers when unaccompanied by dip-arrows indicate spots referred to in the text or from which specimens thus numbered, and now in the Woodwardian Museum, Cambridge, were obtained.

Drift covers the westerly extension of the igneous rocks from Grange Hill. For 'Dunmurry' in the explanation, read 'Dunmurry Hill.'

The top of the hill is formed of igneous rocks, basic and intermediate in character, and these, as shown in fig. 3, are overlain by olive-green grits and gritty shales yielding no fossils except an obscure *Orthis*. No alteration can be detected either in the grits

Fig. 3.—Section 2 on Map.



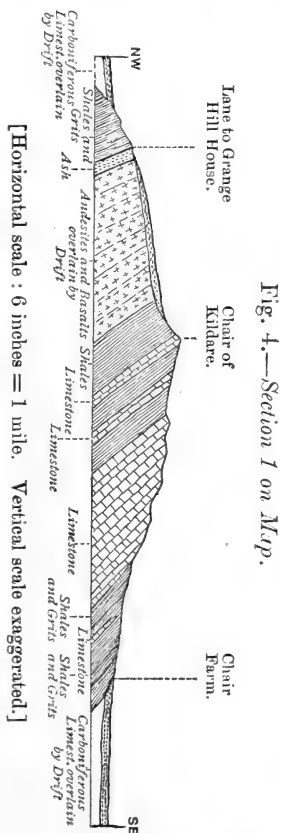
[Horizontal scale : 6 inches = 1 mile. Vertical scale exaggerated.]

and slates above the igneous rocks or in the ashes below them. The igneous rocks are therefore almost certainly contemporaneous, and this view is confirmed by an examination of their structure both in the field and under the microscope. We shall describe these rocks in a later part of this paper.

At the western end of Grange Hill is the Chair of Kildare, where the rocks are markedly different from those forming the main mass of Grange Hill. The lowest bed seen is an ash-band continuous with that which lies immediately below the lavas of Grange Hill. This ash is exposed in the lane leading north-east to Grange Hill House, and between this lane and the Chair no more rocks are seen *in situ*. This tract of country is, however, in the direct line of strike of the lavas of Grange Hill; and it seemed at first as if we had evidence of their extension to this point, from the occurrence of a small quarry exposing numerous blocks of lava which were apparently taken to be *in situ* by the officers of the Geological Survey. After some consideration, however, we came to the conclusion that these blocks were not in place, and that although the lavas probably do extend to this point we have no proof of their doing so.

The limestone of the Chair apparently forms one main mass and several smaller lenticular masses, separated one from another by tracts of country which generally show no exposures and are probably occupied by shales. Sections show that the microscopic characters of the limestone do not vary much in different parts, for everywhere the rock is partly horny, partly crystalline, being formed of well-cleaved plates of calcite. We divide the limestone into four bands, A, B, C, and D, of the same general age.

The succession of the limestone-bands is shown on p. 592, but the thicknesses given for the various beds are only approximate, it being scarcely possible to measure them accurately owing to the difficulty in ascertaining the dip. The limestone, however, has the normal north-east and south-westerly strike of all the beds of Grange Hill, and it dips south-east at a rather high angle. The lowest beds are seen at the foot of the Chair. Taking  $50^\circ$  as the average dip, we have the following section at the top:—



		Feet.
	Calcareous flags and shales of the Chair farmyard .....	15 seen.
	Gap (unseen) .....	about 40
D.	Variable limestone with shaly partings .....	40
	Gap (unseen) .....	about 30
C.	Exposures of red or grey limestone, sometimes horny, sometimes crystalline, with many fossils, are scattered over the next strip of country, about 250 yards wide. We have no evidence against this all being one mass of limestone, though beds of shale may occur in it.....	about 550
	Gap (unseen) .....	20
B.	Red and grey limestone, chiefly horny .....	20
	Green sandy shales and grits of the Earl's Well ...	about 20
	Shaly limestone with basal breccia of shaly fragments in a calcareous matrix.....	14
A.	Red, occasionally grey, horny limestone, becoming crystalline in places .....	16 seen.
	Total .....	765 feet.

The red limestone (A) at the base of the Chair is partly crystalline, partly horny. The two kinds of limestone do not occur in definite layers; sometimes they appear to shade off into each other, but generally they end abruptly. The crystalline limestone is chiefly composed of broken crinoid-stems and fragments of trilobites, especially *Illænus*. The horny limestone has yielded few fossils; it is occasionally greenish, though usually red, and passes up into a shaly limestone with a basal breccia consisting of shaly fragments embedded in an abundant calcareous matrix. These shaly fragments are sometimes so well rounded that the rock might be called a conglomerate. In places the fragments of shale are seen standing out freely on the weathered surface, with their longer axes all arranged parallel to one another. This band (A) is on the line of strike of some greenish grit exposed farther east.

The limestone (A) has yielded the following fossils:—

*Cyathophyllum*, sp.?

Crinoid.

*Agnostus trinodus*, Salt.

*Acidaspis*, sp.

*Ampyx*, sp.

*Cheirurus bimucronatus*, Murch.

*Illænus Bowmani*, Salt.

*Cheinema* (*Pseudosphærexochus*) cf. *conformis*, Ang.

*Sphærexochus latirugatus*, Reed, MS.

*Tiresias insculptus*, M'Coy

*Trinucleus* (?) *concentricus*, Eaton

*Remopleurides longicostatus*, Portl.

*Cyphoniscus socialis*, Salt.

*Discina* cf. *gibba*, Lindstr.

The next overlying beds are the green sandy shales and grits of the Earl's Well. These yielded no fossils.

Next comes the red horny limestone (B), which forms much of the upper part of the Chair, and can be traced away from it both north-east and south-westward. In it we have found:—*Agnostus trinodus*, Salt., *Cyphoniscus socialis*, Salt., *Cheirurus*, sp., *Illænus Bowmani*, Salt., and *Remopleurides longicostatus*, Portl.

The extreme top of the Chair is formed of rock that is not in place. When followed farther north-eastward to a point due north of the Chair Farm, the limestone-band (B) becomes very earthy, and contains the following fossils:—*Atrypa marginalis*, Dalm.,



*Orthis testudinaria*, Dalm., *Orthis vespertilio*, Sow., and *Strophomena (Leptaena) rhomboidalis*, Wilck.

We group all the exposures of limestone on the slope of the hill south and east of the Chair in one broad band (C). This limestone is sometimes red and horny, but is generally grey and more or less crystalline. Fossils are more plentiful in it than in any of the other bands—*Primitia M'Coyi*, *Ilænus Bowmani*, and *Sphærexochus mirus* being specially abundant. It yielded:—

*Cyathophyllum*, sp.  
*Heterocrinus* (?).  
*Primitia M'Coyi*, Salt.  
*Acidaspis cf. evoluta*, Törnq.  
*Cheirurus cf. clavifrons*, Dalm.  
*Homalonotus punctiliosus*, Törnq.  
*Ilænus Bowmani*, Salt.  
 — *cæcus*, Holm  
 — *fallax*, Holm  
 — \**Linnarssoni*, Holm (?=I.  
*Bowmani*, var.)  
*Lichas hibernicus*, Portl.  
 — *lævis*, Eichw.  
 — *laxatus*, M'Coy  
 — *margaritifer*, Nie  
*Phacops*, sp.  
*Proetus cf. ramisulcatus*, Nieszk.  
*Remopleurides longicostatus*, Portl.  
*Sphærexochus latirugatus*, Reed MS.  
 — *mirus*, Beyrich  
*Staurocephalus Murchisoni*, Barr.  
*Ptilodictya acuta*, Hall  
 — *lanceolata*, Goldf.  
*Fenestella assimilis*, Lonsd.

*Atrypa apiculata*, Salt. & Forbes  
 — *expansa*, Lindstr.  
 — *marginalis*, Dalm.  
*Hyatella (Athyris) Portlockiana*,  
 Dav.  
*Leptaena quinquecostata*, M'Coy  
*Orthis alternata*, Sow.  
 — *calligramma*, Sow.  
 — (?) *vespertilio*, Sow.  
*Strophomena (Leptaena) rhomboidalis*,  
 Wilck.  
 — *corrugatella*, Dav.  
 — *expansa*, Sow.  
 — *imbrex*, var., Pand.  
 — *cf. luna*, Törnq.  
*Tripllesia (Orthis) insularis*, Eichw.  
*Streptis (Tripllesia) monilifera*,  
 M'Coy  
*Ambonychia*, sp.  
*Inoceramus trigonus*, Münster.  
*Holopea concinna*, M'Coy  
*Trochus rupestris*, Eichw.  
*Orthoceras suave*, Ang.  
 — *velatum*, Blake

The highest band of limestone (D) is exposed in the field immediately north-west of the Chair Farm, and here a considerable thickness is seen. The lower beds at this locality consist of grey limestone which becomes earthy in places and sometimes has shaly partings. The upper beds are chiefly reddish and horny, and contain few fossils, the commonest being *Favosites fibrosa*.

From the band (D) we obtained the following forms:—

*Favosites fibrosa*, Goldf.  
*Cyathophyllum*.  
 Stromatoporoids.  
*Acidaspis bispinosus*, M'Coy  
*Cheirurus (Pseudosphærexochus) cf.*  
*conformis*, Ang.  
*Ilænus Bowmani*, Salt.  
*Lichas hibernicus*, Portl.  
*Lichas*, sp.  
*Phacops*, sp.  
*Remopleurides longicostatus*, Portl.  
*Harpes Wegelini*, Ang.  
*Ptilodictya lanceolata*, Hall  
*Fenestella assimilis*, Hall

*Lingula ovata*, M'Coy  
*Atrypa marginalis*, Dalm.  
*Orthis alternata*, Sow.  
 — *biforata*, Schloth.  
 — *spiriferoides*, M'Coy  
*Strophomena expansa*, Sow.  
 — (*Leptaena*) *rhomboidalis*, Wilck.  
*Christiania (Leptaena) tenuicincta*,  
 M'Coy  
*Streptis (Tripllesia) monilifera*,  
 M'Coy  
*Tripllesia (Orthis) insularis*, Eichw.  
*Holopea concinna*, M'Coy

Note.—For the determination of very many of our specimens we are indebted to Mr. F. R. Cowper Reed, M.A., F.G.S., to whom we wish to express our most hearty thanks.

The uppermost limestone is succeeded by calcareous flags and shales, which are exposed in the Chair farmyard. From these we obtained :—*Agnostus trinodus*, Salt., *Agnostus*, sp., *Cyphoniscus socialis*, Salt., *Asaphus*, sp., *Trinucleus*, sp., and *Sphaerexochus mirus*, Beyrich.

No other exposures occur till, at about  $\frac{1}{4}$  mile due east of the Chair Farm, there is a small quarry showing hard micaceous grits with shales above them dipping east at  $24^{\circ}$ . After this no more exposures are seen.

As we said before, owing to the compactness of the Chair limestone and the absence of divisional planes, it is extremely difficult to obtain any clear idea as to its dip and thickness. It is evidently a lenticular mass, but appears to have been deposited in much the same state as we now find it, and not to have assumed its lenticular shape as a consequence of the folding and squeezing out of the shales in the way suggested by Messrs. Nicholson and Marr<sup>1</sup> concerning the Keisley Limestone. We never saw in it any signs of crushing and folding, nor of the enclosure of wisps of shale, neither are any of the fossils distorted. Nor did we see any evidence of its being faulted against the rocks to the east in the manner suggested by Messrs. Harkness and Nicholson.

The Chair limestone, as remarked by Messrs. Harkness and Nicholson, is identical in many respects with the Keisley Limestone. The two agree lithologically in varying as regards colour from red to grey, and as regards texture from horny to crystalline. They agree also most closely as regards their fauna.

Although the Chair limestone can be divided into four fairly well-marked bands, yet various forms range through it from top to bottom, and it is probably all on much the same horizon. The four most characteristic forms which range through it are :—*Agnostus trinodus*, Salt., *Ilænus Bowmani*, Salt., *Remopleurides longicostatus*, Portl., and *Cyphoniscus socialis*, Salt.

Though we obtained *Staurocephalus* at a lower horizon, we carefully searched the upper beds without finding any forms characteristic of the *Staurocephalus*-limestone which occurs immediately above the Keisley Limestone in the Lake District. As, however, nearly all the Proterozoic rocks south-east of the exposure of shaly beds in the Chair farmyard are covered with drift, the *Staurocephalus*-limestone may very possibly occur here, though it is not now exposed.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 508, and Marr, Geol. Mag. 1892, p. 101.

## IV. DUNMURRY AND GRANGE CLARE HILLS.

These two hills occur to the south-west of the Chair and Grange Hill, and are cut off from them by a fault which runs along the valley traversed by the Kildare and Rathangan road. The rocks which form these two hills are, as a whole, strikingly different from those forming the hills to the eastward.

The lowest beds found in this part of the inlier crop out along the northern and north-eastern face of Dunmurry Hill. They consist of somewhat black shales, highly ochreous in places, which pass up into more olive-green shales, and are succeeded by a band of red earthy shales. These red beds are very easily marked, and sometimes where they are not seen *in situ* their presence may be inferred from the colour of the soil. They are also seen in the road  $\frac{1}{2}$  mile north of Dunmurry House. We searched all these beds carefully for fossils, but without success. In the Dublin Museum, however, are specimens of *Illeenus Bowmani*, Salt., and *Leptaena quinquecostata*, McCoy, which obviously come from the red beds.

The red shales become more sandy above, and are succeeded by compact grey and greenish micaceous grits which form the main mass of Dunmurry Hill. These beds all have a general S.E.-and-N.W. strike, while that of all the beds east of the fault is N.E.-and-S.W. They dip south-west at an angle of  $25^{\circ}$  to  $35^{\circ}$ .

At the extreme northern foot of Dunmurry Hill, by the hedge, there occurs at one point an exposure of Chair limestone, and east of it a patch of greatly altered lava with porphyritic felspars. We came to the conclusion that these were not in place.

Grange Clare Hill is formed entirely of green and grey micaceous grits with occasional shaly bands. These beds are thrown into a series of folds, as shown by the dip-angles.

## V. SUMMARY OF CONCLUSIONS AS REGARDS THE SEDIMENTARY ROCKS.

We found no palæontological evidence to determine the age of the beds forming Dunmurry and Grange Clare Hills, and the two fossils in the Dublin Museum are insufficient for the purpose, as, although they occur in the neighbouring Chair limestone, they also range up into beds of Valentian age. It seems to us improbable that beds so absolutely different lithologically should be deposited contemporaneously in areas so near together as the Chair and Dunmurry Hills, and we are therefore disposed to think that the Dunmurry beds are of Silurian age. The grit of Dunmurry resembles the grit previously mentioned as exposed in a small quarry  $\frac{1}{4}$  mile east of the Chair Farm, and it is possible that the red and black shales of Dunmurry, as well as the *Staurocephalus*-limestone, may be present in the drift-covered tract of land between the Chair Farm and the grit quarry.

We would, therefore, group the sedimentary rocks of the inlier as follows:—

	DUNMURRY AND GRANGE CLARE HILLS.	CHAIR OF KILDARE AND GRANGE HILL.
?=CONISTON GRITS AND FLAGS.	{ Grey and green micaceous grits and shales forming the main mass of the hills.	Green micaceous grits seen $\frac{1}{4}$ mile east of Chair Farm.
? <sup>1</sup> =STOCKDALE SHALES.		No exposure.

---

No exposure ? horizon of *Staurocephalus*-limestone.

---

CONISTON LIMESTONE  
SERIES.

No exposures.

Flaggy shales with *Trinucleus* in Chair farm-yard.  
 Band D—variable limestone with *Favosites fibrosa*.  
 Band C—crystalline and horny limestone with many fossils, including *Lichas*.  
 Band B—red horny limestone with few fossils.  
 Green sandy shale and grit of the Earl's Well.  
 Shaly limestone and breccia of shaly fragments.  
 Band A—red and grey horny and crystalline limestone of the foot of the Chair.

---

Contemporaneous igneous  
rocks of Grange Hill.

---

Fossiliferous ash of Grange  
Hill House Cottage.  
 Green gritty shales.

## VI. THE IGNEOUS ROCKS OF GRANGE HILL.

The igneous rocks of Grange Hill form the summit of its whole ridge, and extend for nearly a mile in a north-east-and-south-westerly direction. An ash-bed, generally light green in colour, but weathering brown, is exposed frequently along the north-western slope of the hill, and behind Grange Hill House Cottage has yielded abundant organic remains. The beds immediately beneath and above this ash-bed are exposed at a very few places. Close to Grange Hill House there occurs immediately beneath the ash-bed a very vesicular light green andesite, the vesicles being filled mainly with a dark green mineral. A section of the rock shows a groundmass almost entirely

<sup>1</sup> Messrs. Harkness and Nicholson say that the shales of Dunmurry are exceedingly like the Graptolitic Mudstones=Stockdale Shales of the Lake District.

formed of small crystals of oligoclase exhibiting excellent flow-structure, and embedded amongst them occur large porphyritic feldspars, now entirely replaced by calcite and chlorite. The vesicles are filled with a chloritic mineral and quartz, the quartz often showing a partially spherulitic structure. Such an andesite occurs also in a similar position with regard to the ash-bed at the north-easternmost exposure on the hillside. Sections of the ash itself (see Pl. XXVIII. fig. 4) show more or less rounded fragments of lava in which small feldspar-needles are easily recognizable, and these fragments, together with numerous broken feldspars, are embedded in a matrix of calcite and of isotropic brown material. Quartz-grains and patches of a green chloritic mineral are also present. The most interesting exposure of this rock is close to Grange Hill House Cottage, where it becomes more gritty, the quartz-grains increasing in number while the fragments of lava and shattered feldspar-crystals are not nearly so evident; and here, as mentioned above, it becomes very fossiliferous.

Above the ash-bed there is seen in places another band of andesite, also light green in colour, and sometimes very vesicular (see Pl. XXVIII. fig. 5). A section shows a fresh and abundant groundmass composed of acicular plagioclase-feldspars exhibiting flow-structure, granular augite largely replaced by calcite, and much magnetite. One slide also shows some bastite-pseudomorphs after a rhombic pyroxene. The porphyritic constituents are large feldspars, often completely replaced by calcite, while the vesicles are filled with an outer ring of quartz and an inner mass of a chloritic mineral, which is often of a slaty-blue colour in polarized light.

This andesitic flow is covered by a basalt, sometimes dark and compact, sometimes very vesicular. Exposures of this basalt are fairly frequent along the hillside, the rock being recognized by its very fresh black porphyritic augites, sometimes  $\frac{1}{4}$  inch long; occasionally, however, green platy feldspars are the more obvious porphyritic constituents. One of these rocks was found to have a specific gravity of 2.93, and a silica-percentage of 48.15. Some specimens show a red mineral with a good cleavage, occurring as small spots throughout the rock. Under the microscope the groundmass of this rock is seen to consist chiefly of lath-shaped feldspars and grains of augite with a certain amount of interstitial matter. The porphyritic augites are, as a rule, well preserved; they sometimes show a zonal structure, and often occur in groups of irregular crystals; in one instance excellent 'hourglass structure' was clearly seen. The porphyritic feldspars are seldom very fresh, though there is often a kernel of much altered material surrounded by a marginal deposit of fresh secondary feldspar.

The red mineral which has been mentioned above as being visible as spots in a hand-specimen appears to be an iron oxide, generally replacing augite (see Pl. XXVIII. fig. 1). In some cases it occurs as a more or less circular core within a mass of secondary material which fills up completely the space originally occupied by the augite. Sometimes, however, the iron ore is associated directly with augite,

without any other secondary material having been developed. The iron ore is dichroic, being red-brown and purple-brown in colour; in polarized light it assumes a rather brighter red-brown colour, the greatest amount of absorption taking place when the cleavage-lines are parallel to the short axis of the polarizer. Cracks sometimes run through the outer coat of secondary material which are filled with an iron ore distinctly redder than the above-mentioned one, and this is probably hæmatite. The edge of the core, where it comes in contact with the outer ring of secondary material, is very ragged and uneven. In some cases the purplish iron ore occurs not only as the core of the replaced augite, but also in the cracks and as a rim fringing the whole crystal-outline, while in other cases it has come in irregularly. In a few instances the iron ore occurs in relation to little patches of serpentine, which probably represent original crystals of olivine.

Another mineral sometimes present, though found more frequently in the rocks of the Hill of Allen, occurs in the form of small brown or yellow rounded grains with a radiating structure. They can often be completely rotated under crossed nicols without extinguishing. They are found most commonly enclosed in amygdules of chlorite, and are probably chalybite.

Some of these basalts possess large platy feldspars and serve as a link to a peculiarly coarse basalt which is found at the western end of the hill. This is a very striking rock; its junction with the basalts beneath is uneven, and portions of the underlying rock appear to have been enclosed in its base. A hand-specimen shows a grey compact groundmass, in which are numerous greenish feldspars often almost circular in section, sometimes  $\frac{1}{2}$  inch in diameter, and  $\frac{1}{16}$  inch thick. There is a general tendency for these feldspars to be arranged with their flat faces parallel to each other.

A section of this rock shows a groundmass of lath-shaped feldspars, augite, and magnetite. The augite is very much more plentiful in this groundmass than in that of any other rock from the hill; it is allotriomorphic, filling up the spaces between the feldspar-needles, which are not often twinned and give small extinction-angles, being apparently allied to oligoclase. Some serpentine and small crystals of a yellowish pseudomorph after rhombic pyroxene are also present. The porphyritic constituents are, firstly, large plagioclase-feldspars allied to labradorite and often much altered, and secondly, groups of augite-crystals, the individuals of which are frequently well zoned. Amygdules are fairly plentiful; their outermost rim is generally formed of partially spherulitic quartz, within which is a mass of green chloritic mineral, often enclosing numerous small circular spaces filled with clear transparent quartz, which is sometimes beautifully spherulitic.

Though this rock has been found only towards the western part of the hill, and its base is irregular and sometimes encloses portions of the underlying rock, there seems no necessity to consider it intrusive. The adjacent rocks show no sign of alteration, and there

are several rocks among the more basic flows which approach it in character.

Not far south of this exposure of coarse rock—south and south-west of the actual summit of the hill—occurs a patch of an andesite-rock having a compact blue or black groundmass in which small feldspars can be detected on examination of a hand-specimen. Sections of this rock resemble those of the lower andesitic flows. A groundmass of small lath-shaped feldspars, very small augite-grains and magnetite, is to be seen. The small feldspars are allied to oligoclase, and the groundmass shows here and there a perfectly spherulitic structure. Fair-sized porphyritic feldspars occur, much altered, but probably labradorite. Epidote occurs occasionally, and a few amygdulæ are to be seen with an outer rim of epidote and quartz, the latter often showing good spherulitic structure in polarized light. Analyses of this rock gave 55.02 per cent. of silica, and the specific gravity of the rock was found to be 2.82.

The story told by the igneous and other rocks of Grange Hill appears therefore to be this:—After the deposition of the unfossiliferous muds and sandy shales now found along the base of the north-western slopes of the hill, the period of igneous activity was heralded by a slowly creeping flow of andesite; this made its way along the sea-floor without producing any apparent chemical alteration in the beds over which it crept. Soon, however, the ashes which no doubt accompanied the outburst of lava settled down as a thin deposit on its surface, enclosing here and there the animal remains which are now found fossilized and give us proof that all this occurred in Middle Bala times. The deposit of ashes was then covered by another andesitic flow, and then the nature of the lavas which crept over this portion of the sea-floor altered. They became more decidedly basic and basaltic in character, the alteration in chemical composition being accompanied by a darkening in colour, and the more obvious and frequent occurrence of augites. These rocks, too, are very vesicular in places, though the flow-structure is not visible under the microscope as it is in the earlier andesitic flows. The large feldspars that floated along are, however, all arranged with their long axes pointing more or less in one direction, and testify to the fact that these rocks, too, crept along the sea-floor and are true lavas. The upper surface of these flows—no doubt very rugged and uneven—was then covered by a very much coarser basalt, and as the latter crept along it appears to have broken off pieces of the underlying flows and incorporated them with itself. This flow also was vesicular, and appears to be covered at one locality by a second flow of andesite. After this igneous action ceased, and the deposition of mud and sands once more occurred. But in places to which mud and sand were not brought limestones were laid down, and finally the whole was covered by the sandy beds which now form the grits that occur south-east of the Chair.

## VII. THE HILL OF ALLEN.

At the present time no sedimentary rocks are exposed on the Hill of Allen, and the succession of the igneous rocks is by no means easy to make out. There are several well-marked bands of rock which strike roughly north-east and south-west, but the direction of their dip is not very clear.

The ashes and andesites seen at the base of the igneous rocks of Grange Hill have no representatives exposed on the Hill of Allen, where the lowest rock seen is that at the base of the south-eastern face, and is a dark vesicular basalt, generally characterized by the presence of porphyritic augites. Under the microscope, porphyritic feldspars are to be seen as well; these are, however, nearly always greatly altered, though the alteration-products are commonly rimmed with fresh secondary feldspar. In a rock from the spot marked 60 on the map (fig. 1, p. 588) many of the feldspars are very fresh and well twinned.

Resting on this comes another basalt, fine in texture, showing no porphyritic constituents in a hand-specimen, and generally somewhat red in colour, though occasionally green. This rock is often very vesicular, the vesicles being filled either with calcite or chlorite. Some sections show a groundmass deeply stained with hæmatite and containing many small feldspars. The porphyritic constituents include fair-sized plagioclase-feldspars with their margins much fretted and their substance entirely replaced by alteration-products. Large fresh augites occur aggregated together, and there is present, as on Grange Hill, a mineral in the form of shapeless grains often crossed with curved cracks. These grains are generally surrounded by a deep red-brown rim of hæmatite which also fills the cracks, while the spaces between the cracks are now often occupied by serpentine. There seems every probability that these were originally grains of olivine. Grains of chalybite are often found quite similar to those in the rocks of Grange Hill.

These basalts are, we think, to be correlated with those which immediately overlie the lowest andesitic flows of Grange Hill. Amongst both we find rocks sometimes dark green, sometimes red, showing sometimes porphyritic augites, sometimes porphyritic feldspars. Sections of these rocks from both hills show augite-crystals aggregated together, and porphyritic feldspars which have been entirely replaced by alteration-products and afterwards rimmed with fresh feldspathic material. The occurrence of chalybite, and of pseudomorphs after olivine, is also characteristic of both hills.

On the Hill of Allen, as on Grange Hill, these basalts are overlain by a coarse porphyritic basalt, the junction between the two being in some places very sharp and in others more or less irregular. At some points there seem to be portions of the fine basalt caught up in the coarser rock, and this is particularly noticeable at a point east of the tower on the top of the hill, where a well-marked but very local breccia occurs. This breccia consists of blocks of both the coarse and fine rocks mingled together. The blocks and frag-



ments include both rounded and angular individuals, and are of all lengths up to about a foot. This irregular base to the coarse rock was also noticeable to some extent on Grange Hill.

The coarse rock occurs along two parallel lines on the south-eastern face of the hill, the lower line ending off abruptly about 30 feet below the point where the upper line as abruptly begins. There seems to be a small fault here causing this discontinuity. Exposures of the coarse rock also occur at various points on the western face of the hill, and one small exposure was found low down the hill-side, due east of the Carrick tower.

The appearance of this rock in the field is exactly like that of the coarse basalt from Grange Hill. There is the same grey, somewhat crystalline groundmass enclosing the same large white or greenish-white porphyritic feldspars, which are often almost circular in outline and of no great thickness, while most of them lie with their flat faces parallel to each other. Vesicles filled with calcite and a chloritic mineral are similarly to be observed in the rocks from both hills.

Under the microscope the resemblance between the coarse rocks of the two hills holds equally well (see Pl. XXVIII. fig. 2). In each we see the same prominent groundmass formed of small idiomorphic crystals of plagioclase and allotriomorphic granules of augite in almost equal proportions, the same development of magnetite, green serpentine, and yellowish pseudomorphs after a rhombic pyroxene, while the porphyritic constituents in the two cases are seen to be fresh augites and large feldspars allied to labradorite.

Most of the upper part of the hill is formed of an andesitic rock [67, 78], which overlies the coarse basalt and has a very definite character. It is rather light green in colour and marked with numerous red spots which are patches of hæmatite. A hand-specimen shows no obvious porphyritic feldspars, but many fresh black augites are to be seen.

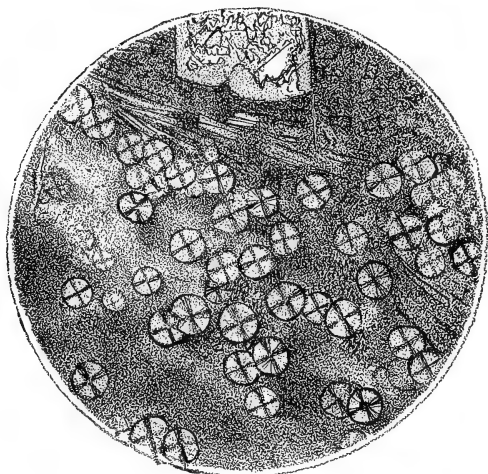
Under the microscope (see Pl. XXVIII. fig. 6) it is seen to be characterized by having a groundmass crowded with small rectangular or nearly square sections of a fairly fresh feldspar allied to oligoclase; but it contains also augite, bastite-pseudomorphs after a rhombic pyroxene, and magnetite. Porphyritic feldspars occur, much altered and epidotized, but possessing an outer rim of fresh secondary feldspar. Porphyritic augite and altered rhombic pyroxene are to be seen, the two minerals being sometimes intergrown in a complicated manner (see Pl. XXVIII. fig. 3). It is the occurrence of abundant small feldspars which appear square or rectangular in section that marks off this hypersthene- or enstatite-augite-andesite from the other rocks of the hill. An analysis of this rock showed 58.5 per cent. of silica, while the specific gravity was 2.81.

The rest of the north-western slope of the hill is formed of rocks dark in colour, which show very obvious porphyritic feldspars in a hand-specimen. They almost invariably show bastite-pseudomorphs after rhombic pyroxene, augite, and magnetite in their groundmass, together with feldspars having low extinction-angles, while the

porphyritic constituents are fair-sized plagioclase-feldspars and augites. The feldspars are very greatly altered, but are generally rimmed with a layer of fresh material; the augites occur in masses of aggregated crystals, often accompanied by rhombic pyroxene.

In two rocks from different ends of the hill porphyritic hornblendes, showing the characteristic cleavage and pleochroism, are to be seen. The crystals are much fretted away, and replaced round their margins by fringes in which one can recognize magnetite and hæmatite. These marginal fringes occur round all the hornblendes, while here and there patches of similar constitution occur without any central hornblende, though no doubt the patches have been formed from hornblendes in the same way as the fringes. One of these rocks, from the spot marked 80 in the map, has 52·8 per cent. of silica, and its specific gravity is 2·8. This rock is also noticeable for the presence of amygdules of chlorite enclosing beautiful little spherulites of quartz similar to those of Grange Hill (see fig. 5).

Fig. 5.—*Hornblende-andesite* [80], *Hill of Allen*.  $\times$  about 40.



The section was drawn in polarized light, and shows a large patch of a chloritic mineral enclosing numerous little spherulites, probably of quartz, all with the characteristic black cross.

At the northern end of the hill occurs a fine dark-coloured, sometimes vesicular, compact basalt, more or less in the line of strike of the last-mentioned rocks. Sections of this rock are remarkable for the large amount of magnetite in the groundmass, and its aggregation round some of the vesicles and feldspars in a way sometimes recalling the appearance of micropegmatite. The feldspars are much altered, and give a low extinction-angle. The augites form large plates, and are sometimes very fresh, sometimes much altered.

It will thus be seen that the rocks of Grange and Allen Hills are very closely allied. On both hills we meet with:—(1) rocks which have large aggregated masses of augite-crystals; (2) rocks with what are probably pseudomorphs after olivine; (3) rocks with large labradorites; (4) rocks with the groundmass largely formed of small feldspars with square or rectangular cross-sections; (5) rocks with bastite-pseudomorphs after a rhombic pyroxene; (6) rocks with altered feldspars, whose margins are made up of fresh secondary feldspar; (7) rocks with plentiful spots of chalybite; (8) rocks with large vesicles filled with a chloritic mineral or serpentine in the centre, and round the margin with quartz, which is often partially spherulitic and sometimes encloses very perfect little spherulites.

There is thus plenty of evidence that the igneous rocks of the Hill of Allen are very similar to those of Grange Hill; and although no sedimentary rocks are exposed now on the Hill of Allen, we consider it quite certain that these igneous rocks are of Bala age, and that they are all of the nature of lava-flows.

The greater area covered by these rocks on the Hill of Allen, as compared with Grange Hill, may best be accounted for by an alteration in their dip due to a fault between the two hills, running in a direction more or less parallel to the fault at the base of the Chair of Kildare. The beds of the Hill of Allen differ, however, from those of Grange Hill not only in the amount of their dip, but also in its direction, for they appear to dip to the north-west.

#### VIII. SUMMARY OF CONCLUSIONS AS REGARDS THE IGNEOUS ROCKS.

Taking Grange and Allen Hills together, four groups of rocks may be made out:—

- (1) Rocks with abundant feldspar-needles in the groundmass, showing good fluxion-structure: as, for example, the andesites of the northern foot of Grange Hill.
- (2) Rocks with the groundmass largely formed of fair-sized, often fresh, square-edged crystals, including, as a rule, also rhombic pyroxene and patches of hæmatite: as, for example, the greenish hypersthene-augite-andesite [67, 78] high up on the Hill of Allen and sometimes of Grange Hill.
- (3) Rocks with a groundmass formed of a crystalline matrix of feldspar and augite, the latter not in definite crystals, but filling up the spaces between the feldspars; very large labradorites and some serpentine present: as, for example, the porphyritic basalts of both Grange and Allen Hills [5, 73].
- (4) Rocks with a fairly plentiful groundmass consisting of feldspar-needles and some augite and magnetite; the porphyritic constituents consist of much-altered feldspars and large fresh augites, often aggregated together in groups: as, for example, the basalts found along the eastern base of the Hill of Allen and some of those of Grange Hill.

The general arrangement of the igneous rocks of Grange and Allen Hills may be shown in the following synopsis :—

At the top :

GRANGE.

5. Andesite forming a small patch overlying the porphyritic basalt towards the south-western end of Grange Hill.
4. Porphyritic basalt, with large crystals of labradorite.
3. Basalt, sometimes amygdaloidal, sometimes with large fresh augites.
2. Augite-andesite, often showing good fluxion-structure.
1. Band of ash seen along the northern foot; below it, at two points, lava is visible.

ALLEN.

5. Variable rocks, the best-marked being the hypersthene-augite-andesite having a groundmass crowded with square or rectangular feldspars.
4. Porphyritic basalt, with large crystals of labradorite.
3. Basalt, sometimes amygdaloidal, sometimes with large fresh augites. Its colour is red or dark green, and it occurs along the south-eastern face of the hill.
2. Not seen.
1. Not seen.

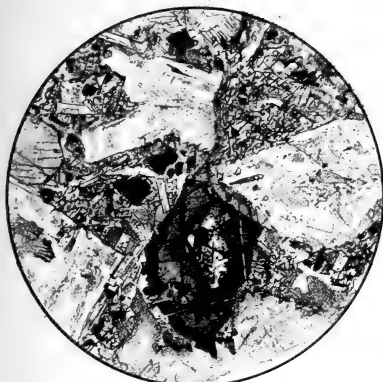
IX. GENERAL CONCLUSION AND SUMMARY.

All the rocks exposed in the Kildare inlier are either of Silurian or of Ordovician age. Those lying west of the fault which runs between Dunmurry Hill and the Chair are probably of Silurian age, while the fossiliferous beds east of the fault show that we are here dealing with rocks of Ordovician age. With the doubtful exception of one exposure of grit, all the beds east of the fault are referable to the Middle Bala.

Grange Hill and the Hill of Allen are mainly composed of contemporaneous igneous rocks, all the lavas being of the nature of basalts or andesites. We found no clear evidence of the occurrence of intrusive rocks anywhere in the inlier. The igneous rocks of Grange Hill are overlain and underlain by sedimentary deposits containing Middle Bala fossils. With regard to the age of those of the Hill of Allen, we have no definite evidence; but their resemblance to those of Grange Hill is so great that we feel justified in regarding them, and so the whole of the igneous rocks of the area, as of the age of Sedgwick's Middle Bala.

We wish to express our best thanks for kind help to Messrs. Marr and Harker, and especially to Mr. W. W. Watts and Mr. Cowper Reed; also to Prof. Sollas and various members of the Irish Geological Survey, for the privilege of referring to the Survey Maps at Dublin. Also to Mr. P. Doyle, of the Chair Farm, Kildare, for his uniform courtesy.

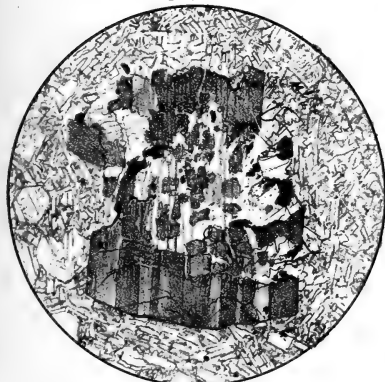
1x35.



2x9.



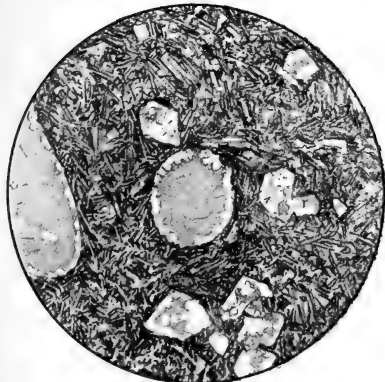
3x9.



4x23.



5x9.



6x9.





## EXPLANATION OF PLATE XXVIII.

[The numbers in square brackets indicate spots marked in the maps.]

- Fig. 1. Olivine ?-basalt [8], Grange Hill, Kildare.  $\times 35$ .

The dark patch is a pseudomorph of hæmatite and another red oxide of iron, probably after olivine. The drawing shows also crystals of augite and of altered felspar. The groundmass consists of felspar-needles, small patches of augite and iron ores.

- Fig. 2. Porphyritic basalt [73], Hill of Allen.  $\times 9$ .

The groundmass consists mainly of small felspar-crystals and fresh grains of augite in nearly equal proportions. The porphyritic constituents consist of very large, much-altered crystals of labradorite, and rounded crystals of augite, two of which are shown in the upper part of the drawing.

- Fig. 3. Augite-andesite [78], Hill of Allen.  $\times 9$ .

The drawing shows a large twinned crystal of augite, the central portion of which is intimately intergrown with a pale rhombic pyroxene. The augite encloses also several small patches of magnetite. The character of the groundmass is similar to that of fig. 6.

- Fig. 4. Andesite-tuff [30], Grange Hill, Kildare.  $\times 23$ .

The drawing shows angular fragments of two varieties of andesite embedded in a matrix of smaller fragments, broken felspar-crystals, and fine particles.

- Fig. 5. Amygdaloidal augite-andesite [29], Grange Hill, Kildare.  $\times 9$ .

The groundmass consists mainly of small felspar-needles, and shows good fluxion-structure. Embedded in it are numerous amygdules of a chloritic mineral and quartz. The larger amygdules, which are more or less circular or oval in section, have a rim of quartz, while the main part is occupied by the chloritic mineral.

- Fig. 6. Augite-andesite [68], Hill of Allen.  $\times 9$ .

The drawing shows numerous small, square-edged felspars, also larger porphyritic felspars, which are greatly altered, but are bordered by a rim of fresh secondary felspar.

Fig. 3 is the only one in the Plate drawn in polarized light.

## DISCUSSION.

Mr. W. W. WATTS called attention to the presence of olivine and hornblende in the contemporaneous igneous rocks of Kildare. The former mineral was almost unknown, and the latter decidedly rare, in the great Welsh province of this date.

The PRESIDENT and Mr. GARDINER also spoke.

35. *EXTRUSIVE and INTRUSIVE IGNEOUS ROCKS as PRODUCTS of MAGMATIC DIFFERENTIATION.* By Prof. J. P. IDTINGS, For. Corr. G.S. (Read June 24th, 1896.)

[PLATE XXIX.—MAP.]

PROF. W. C. BRÖGGER, in dedicating to me his recent work on 'Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Südtirol,'<sup>1</sup> has not only honoured me by this token of his friendship, which I prize highly, but also by associating my name with a work which commands my admiration, and with which I am in the most hearty accord. His treatment of the igneous rocks in the region of Predazzo as a generic series intermediate in composition between a granite-diorite-gabbro series and a granite-syenite (elæolite-syenite) series is fully justified by their chemical and mineral composition and by their geological association; and for the order in which these rocks have been erupted he has given ample evidence. The intrusive character of the granular rocks is clearly established, and the fantastic theory of Reyer abundantly disproved. So also the discussion of Kjerulf and Michel-Lévy's hypotheses, regarding the melting and assimilation of overlying rocks by molten granitic magmas, leaves nothing to be said in further refutation of these suggestions, so far as they relate to the intrusion of igneous magmas that come within the range of our investigation. To suppose that such a process may have been active in the earliest period of the cooling globe is quite reasonable. It implies a very highly-heated magma, and shifting temperature or convection-currents. As applied by Suess<sup>2</sup> to account for the great craters of the moon, it appears highly probable. But there is no evidence that such a melting has taken place in the case of the intrusion of igneous rocks, except to a very limited extent. The remarks of Brögger on this subject also express the conclusions of those who have studied the phenomena of intrusive rocks in the United States.

In his closing argument relating to the order of eruption, and to the differentiation of igneous magmas as exemplified in groups of intrusive and extrusive rocks, he reaches, however, conclusions which are different from those to which a study of the igneous rocks in certain parts of Western America must necessarily lead one. And since he has cited the occurrence of igneous rocks at Electric Peak and Sepulchre Mountain in the Yellowstone Park<sup>3</sup> in support of his position, it is only right that I should explain, more fully than I

<sup>1</sup> 'Die Eruptivgesteine des Kristianiagebietes.' II. Videnskabs-selskabets Skrifter I. Mathematisk-nat. Klasse, 1895, no. 7.

<sup>2</sup> Suess, E., 'Einige Bemerkungen über den Mond,' Sitzungs. d. k. Akad. d. Wissensch. Wien, vol. civ., Feb. 1895.

<sup>3</sup> Iddings, J. P., 'The Eruptive Rocks of Electric Peak and Sepulchre Mountain, Yellowstone National Park,' 12th Annual Report U.S. Geol. Surv., pp. 569-664, Washington, 1891.



did in the description of those rocks, the relation of that series of eruptions to the whole series of which it is but a part.

Prof. Brögger says in effect that he has considered only the case of the order of eruption of deep-seated rocks (*Tiefengesteine*) because they alone can furnish a correct idea of the primary differentiation which takes place in the primitive magma or in the 'magma-basin.' For after certain portions have been separated from the primitive magma by being erupted into deep-seated parts of the earth's crust, further differentiation may take place in this portion producing basic and acid complementary rocks, which may be further erupted in the form of dykes, or may be extruded upon the surface of the earth. And since this may take place in each deeply-seated body of magma, separated successively from the magma-basin, there may be in one region successive, or repeated, series of eruptions in which the rocks range from basic to acid. The order of succession of this compounded series of eruptions would not be the same as that of the series of eruptions emanating from the so-called magma-basin. And the characters of the rocks produced by the subsequent differentiation of the separate magmas, derived from the primitive magma, may be distinct from those produced by the direct differentiation of the primitive magma. For this reason, results obtained by a study of the order of succession of extrusive rocks must be critically examined before employing them to explain the order of eruption or the character of the differentiation of primitive magmas, or of those in so-called magma-basins.<sup>1</sup>

<sup>1</sup> 'Im Obigen ist nur von der Eruptionsfolge der *Tiefengesteine* die Rede gewesen. Es ist nach meiner Ansicht absolut nöthig, bei der Ableitung der gesetzmässigen Beziehungen der Altersfolge der einer Eruptionsepoche zugehörigen Eruptivgesteine, nicht ohne weiteres die Erfahrungen von den Verhältnissen der Tiefengesteine auch auf die *Ergussgesteine*, und umgekehrt, zu übertragen.

'Bei den *Ganggesteinen* ist es schon jetzt eine allgemeine Erfahrung, dass Gruppen von basischen und sauren Ganggesteinen als complementäre Gänge den verschiedenen Eruptionen der Tiefenmassen entsprechen. Innerhalb der Geschichte der ganzen Eruptionsepoche würden wir somit für die Ganggesteine, wenn diese allein berücksichtigt werden sollten, eine oft wiederholte Aufeinanderfolge von basischen und sauren Gesteinen als die normale Eruptionsfolge bezeichnen müssen.'

.....  
'Nun ist es aber selbstverständlich nicht nur denkbar, sondern im Allgemeinen sogar sehr wahrscheinlich, dass dieselben Spaltungsmagmen, welche in den Gangspalten als hypabyssische Gesteine erstarrt sind, *theilweise auch die Tagesoberfläche erreichen konnten und hier oft mit anderer Mineralienzusammensetzung und Structur, als Ergussgesteine, als Decken und Ströme etc. erstarren.*

'In derartigen Fällen würden wir bei der Bestimmung der gegenseitigen Altersbeziehungen der einer bestimmten Eruptionsepoche angehörigen *Ergussgesteine* wieder eine Altersfolge von basisch—sauer, etc., mit mehrmals wiederholtem Wechsel erhalten können.

'Die Altersfolge der primären Differentiationen, die Reihenfolge der primären Aufpressungen der differenzirten Magmen aus dem Magmabassin selbst würden wir aber wieder *nicht* erhalten. Diese lässt sich allein durch das Studium der Altersbeziehungen der grossen Massen der Tiefengesteine ableiten.

'Aus diesem Grund müssen die Untersuchungen über die relativen Alters-

The statement is made that the order of eruption of extrusive rocks is for the most part dependent on relatively secondary differentiation. It is also stated that the order of primary differentiation and the succession of primary eruptions of the differentiated magmas from the 'magma-basin' can be learned only from the study of the relative ages of the great masses of deep-seated rocks.

Prof. Brögger then comments at some length upon the general order of eruption as set forth by me in the paper on 'The Origin of Igneous Rocks,' namely, that the succession is generally from rocks of intermediate to those of more and more extreme composition.<sup>1</sup> And he calls attention to the fact that the conclusions were drawn almost entirely from observations upon extrusive rocks. In these cases also he notes numerous exceptions, and moreover points out that the parent magmas (*Stamm-magma*) may not always be of like composition. These points, too, were mentioned in the paper cited (pp. 178, 183).

Upon some of the propositions in question Prof. Brögger and I are in perfect accord, in others we seem to be at variance. We agree as to the fact that the differentiation of magmas intruded into the earth's crust from greater depths produces complementary rocks, which may take the form of dykes (Rosenbusch's *Ganggesteine*) or may reach the surface as lava-streams, etc.; that the order of eruption of these products may lead to recurrent series, both among intrusive and among extrusive bodies; that these series, as a whole, would not represent the differentiation that took place in the original parent magma. All parent magmas do not have the same composition. The magmas first derived from them certainly do not have the same composition, consequently the groups of differentiation-products belonging to various derived magmas will present distinct series. And of course the intermediate member of one of these series is like the magma from which the series was directly derived. It has not a fixed composition corresponding to one intermediate for all known rocks.

Eruptions from a body of molten magma into outlying or overlying regions may take place before a differentiation of this particular magma sets in, or after it has progressed little or much. The composition of the various portions of magma drawn off will depend on a variety of conditions, which might be postulated at length. If extrusive bodies of rock be considered apart from their

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beziehungen der Ergussgesteine immer mit kritischer Vorsicht benutzt werden, wenn man die Differentiationsgesetze der Tiefenmagmen und ihren Einfluss auf die Altersfolge der Eruptionen einer Eruptionsepoche studiren will; in der obigen kurzen Übersicht wurden deshalb auch fast ausschliesslich bekannte Beispiele der Altersfolge *plutonischer* Gesteine berücksichtigt, während die Altersfolge der Ergussgesteine *als zum grossen Theil von relativ sekundären Differentiationen abhängig*, vorläufig ausser Acht gelassen wurde.' (*Op. jam cit.* pp. 177, 178.)

<sup>1</sup> Iddings, J. P., 'The Origin of Igneous Rocks,' Bull. Phil. Soc. Washington, vol. xii. (1892) p. 145.

proper intrusive connexions, it is clear that, since all the portions of magma erupted from a reservoir of magma may not reach the surface of the earth, the series of lavas which have been extruded may be a partial series, imperfect at the beginning or end, or anywhere between. And the same must be true for any disconnected group of intruded bodies.

On all these points we agree. The points of difference seem to be the following:—That the order of primary differentiation and eruption can be learned only from a study of large bodies of deep-seated igneous rocks; and consequently that the bodies of extrusive rocks from which my conclusions were drawn are not adequate for the solution of the problem; that the range from intermediate to greater and greater extremes is not of very general application, and that the order of succession of the rocks at Electric Peak represents a more general law, namely, that the succession is usually from basic to acid, often followed by basic as the last.

In order to defend my position from this friendly attack, it is necessary to picture as vividly as I can the relation of the igneous rocks at Electric Peak to all those that took part in the great series of eruptions which occupied almost the whole Tertiary period, and spread themselves over an enormous territory lying in Montana, Wyoming, and Idaho.

The extent of this great period of volcanic activity, though vast, is well marked in this region.<sup>1</sup> During the longer periods of time during which Palæozoic strata were being deposited, no outburst of igneous rock took place. The same is true for all the Mesozoic period until after the Laramie coal-bearing layers had been formed: the whole of this great series being nearly conformable throughout. At the end of Cretaceous time, there were great orographic movements, by which the region was profoundly faulted and dislocated.

Volcanic action began at this time, and fragments of igneous rocks are included in the sandstones immediately overlying the coal-bearing Laramie.<sup>2</sup> There was also extensive denudation whereby the sedimentary strata were in places entirely removed from off the underlying crystalline schists. Into these disturbed strata the igneous material was forced, and upon the uneven surface of the country it was spread out, covering crystalline schists in one place, and upturned limestones and sandstones in another. In most cases the character of the eruptions was extremely violent. At first they were largely explosive, shattering the surface-rocks, whether gneiss or limestone, and scattering them broadcast to form the first layer of tuff-breccia, or to be intimately mingled with fragments of lava. The explosive character prevailed until a great accumulation of tuff-breccia formed a chain of lofty volcanoes com-

<sup>1</sup> Hague, A., 'Geological History of the Yellowstone National Park,' Trans. Am. Inst. Mining Engineers, vol. xvi. (1888) p. 783; also *Compte-rendu 5ème Sess. Int. Congr. Geol.* Washington, 1891, p. 338, and 'The Age of the Igneous Rocks of the Yellowstone National Park,' *Am. Journ. Sci.* ser. 4, vol. i. (1896) p. 445.

<sup>2</sup> Weed, W. H., 'The Laramie and the overlying Livingston Formation in Montana,' *Bull. U.S. Geol. Surv.* No. 105, pp. 12 & 21, Washington, 1893.

parable with those of the Andes in size, as well as in the nature of their material. The later eruptions from these volcanoes were quieter outflows of lava, which probably took place after the position of the volcanic conduits had become more stationary. Erosion having carried away the upper parts of these great cones, the remaining portions are almost wholly made up of breccia, in places 4000 feet thick.

The last of the great eruptions were equally violent, though of a different kind. They were gigantic fissure-eruptions that flooded the region west of the chain of denuded volcanoes with massive streams of lava that rose high up on the flanks of the surrounding mountains, and then flowed toward the south-west, leaving, when cooled and after erosion had somewhat reduced the surface of the stream, a vast sheet of lava at least 1000 feet thick in most places, and over 2000 feet thick in some parts. This was followed by other outflows from fissures that flooded the region for hundreds of miles to the south-west and west, and closed the period of activity. Within the Yellowstone Park the earliest breccias were accumulated in Eocene time, and the great bulk of the Absaroka volcanoes in Miocene; while the great fissure-eruptions just mentioned took place in the Pliocene.

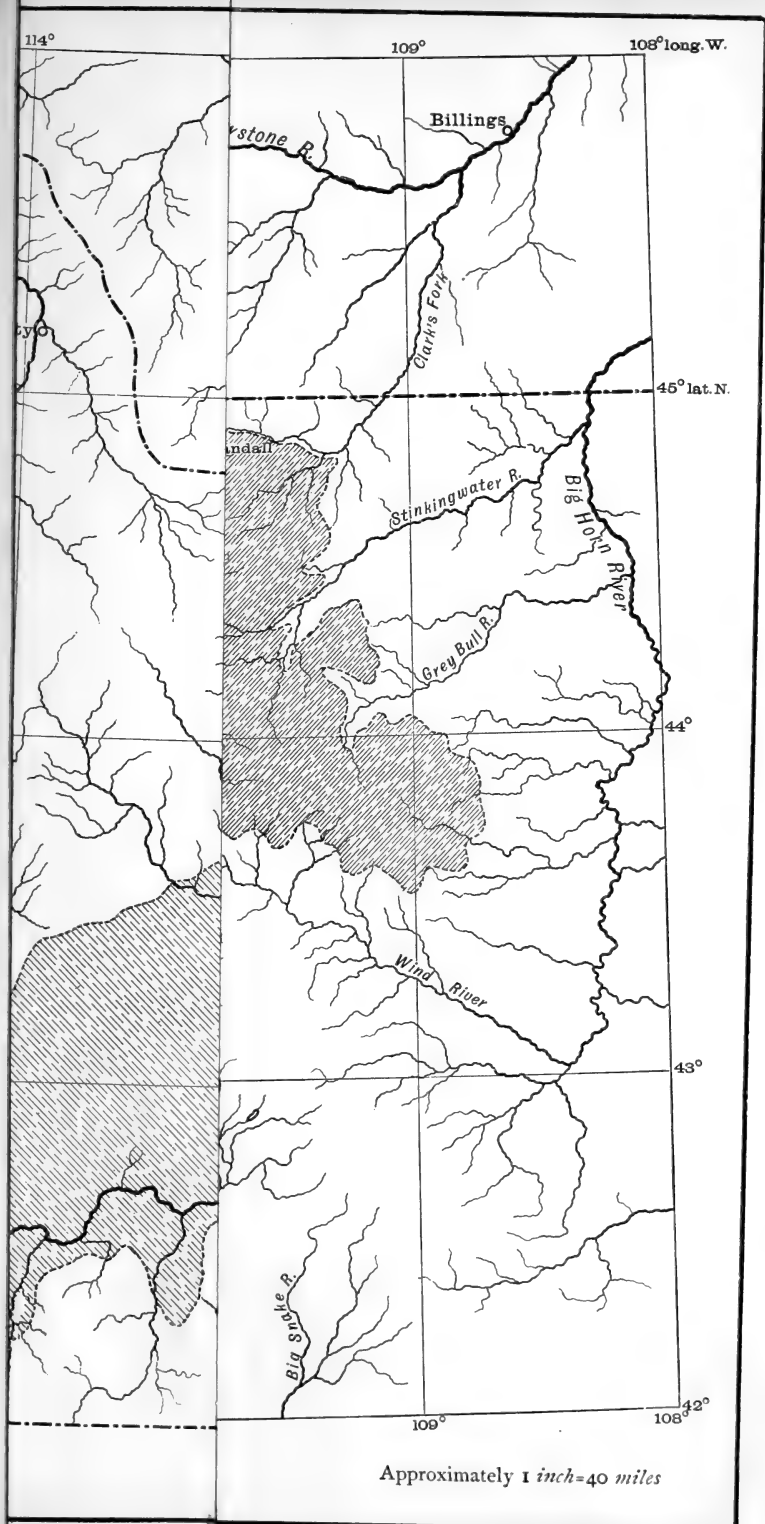
With this crude sketch before us, let me attempt to fill in, as it were, some of the details. To this end I have drawn an outline-map of the territory involved, indicating only the drainage and the surface-distribution of the volcanic rocks. The chain of volcanoes which is now represented by the tuff-breccias and included lava sheets, dykes, stocks, etc., extends without interruption from immediately south of Bozeman, Montana, at about lat.  $45^{\circ} 30'$ , southward 40 miles in the Gallatin Mountains, to a short distance within the northern boundary of the Yellowstone Park.<sup>1</sup> It extends eastward about 50 miles through the southern half of the Snowy Mountains along the northern boundary of the Yellowstone Park, to the head-waters of Clark's Fork River. Thence southward in Wyoming it forms the Absaroka<sup>2</sup> range along the eastern boundary of the Park,<sup>3</sup> and continues beyond the head-waters of the Yellowstone River to the head-waters of Wind River, where it forms the rugged peaks about Togwotee Pass and the Washakee Needles,<sup>4</sup> terminating at about lat.  $43^{\circ} 30' N.$ , or 105 miles from the last-mentioned bend. The length of the chain is about 170 miles. In the north it is at present 12 or 15 miles wide, and in the Absaroka range from 25 to 50 miles wide. The volume of igneous rock that was erupted to form this range must have been enormous, when

<sup>1</sup> Iddings and Weed, 'Livingston Folio, Geologic Atlas of the United States,' no. 1, Washington, 1894.

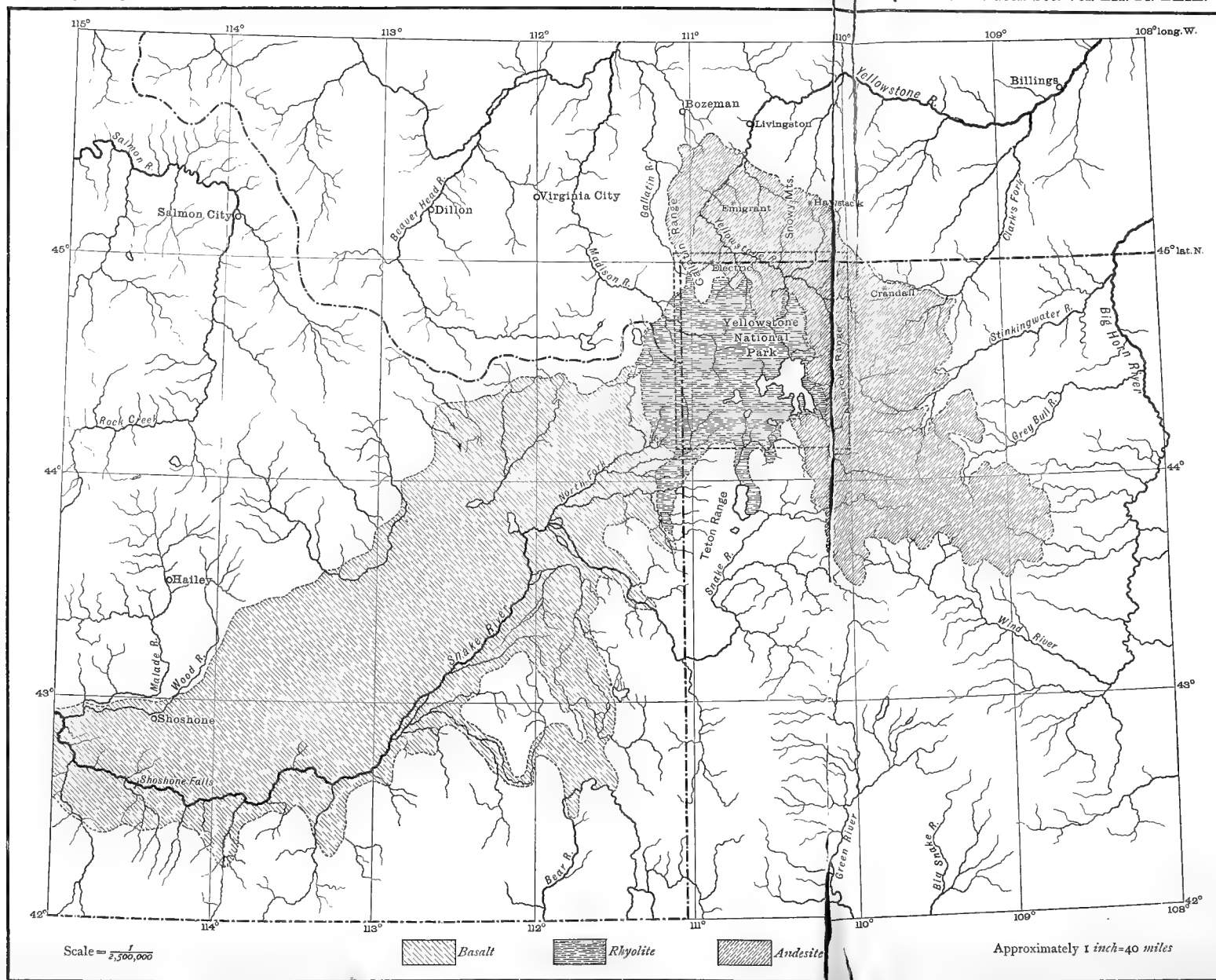
<sup>2</sup> Misprinted 'Assaroka' in the accompanying map (Pl. XXIX).

<sup>3</sup> Hague, A., *Compte-rendu 5<sup>ème</sup> Sess. Int. Geol. Congr. Washington, 1891*, p. 339; also Iddings, 'A dissected Volcano of Crandall Basin, Wyoming,' *Journ. Geol.* vol. i. (1893) p. 606.

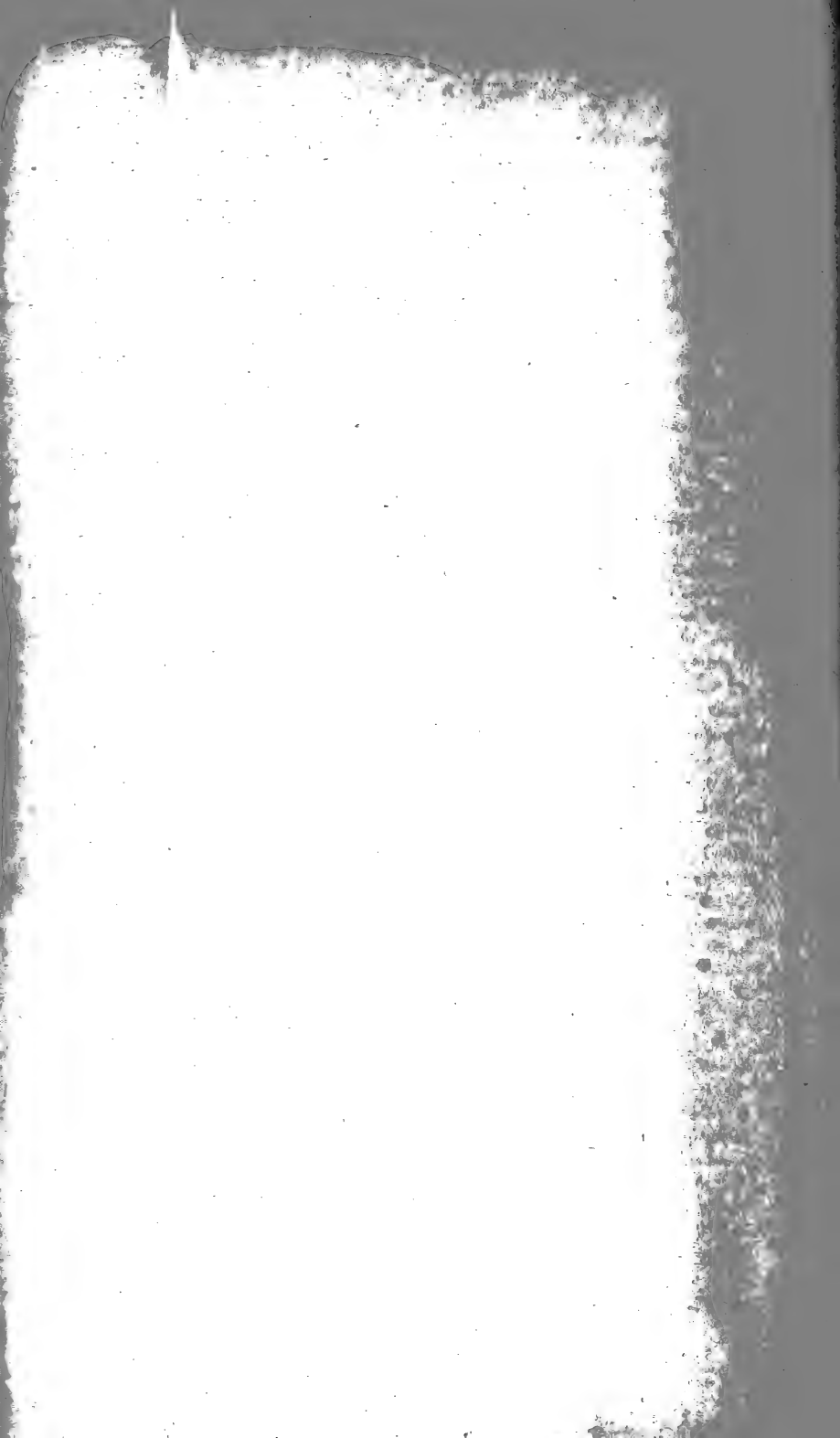
<sup>4</sup> St. John, O., Report in Hayden's 12th Ann. Rep. U.S. Geol. & Geogr. Surv. of the Territories, pt. i. p. 260, Washington, 1883.







MAP OF PORTIONS OF IDAHO, MONTANA, AND WYOMING, SHOWING IN PART THE DISTRIBUTION OF THE VOLCANIC ROCKS.





we remember that the Crandall volcano represented a pile of volcanic material at least 13,500 feet high, and that there were others like it. The present surface-extent of this range of volcanoes is over 4000 square miles, and the present thickness of the breccias is from 2000 to 4000 feet. When the great erosion from the summits is taken into account, and the shrinkage of its borders from denudation and by being covered by subsequent fissure-eruptions is included, an original volume of 4000 cubic miles is an estimate within the bounds of reason.

Almost the whole of this material is andesite and andesitic basalt, ranging in percentage of silica from 65 to 52. The parts that would lie outside of these limits do not constitute 1 per cent. of the whole, so far as my knowledge and judgment go. Small bodies with exceptional composition occur, and will be referred to again. But the great mass of the mountains consists of hornblende-mica-andesites, hornblende-andesites, hornblende-pyroxene-andesites, pyroxene-andesites, olivine-bearing andesites, and andesitic basalts.

These have been erupted in the following order:—First, hornblende-mica- and hornblende-andesites with some dacite, forming light-coloured, mixed breccia, usually containing fragments of crystalline schists and of sedimentary rocks. The volume of this breccia is small when compared with that of the overlying dark-coloured and less siliceous breccia. Its average percentage of silica would be about 62. It has suffered some erosion before being covered by the second breccia, but appears to grade up into it in places. The overlying breccia grades upward from hornblende-pyroxene-andesite through pyroxene-andesite to andesitic basalt, the least siliceous varieties being uppermost. The proportions of these varieties are about equal, and together they form about one-half the whole mountain-range, beginning at the northern end—that is, originally about 2000 cubic miles. Upon the basaltic top of this series was ejected a second series almost identical with the first. This later series constituted the remaining half of the mountain-range, and formed volcanoes that have been eroded in the same manner as those farther north. In each of these series of eruptions the variation was from more siliceous to less siliceous; and the range of silica-percentages is from about 65 to about 52: the average percentage in each case being probably about 57 or 58.

With these accumulations of andesitic breccias are a number of bodies of intrusive rock, whose bulk, however, is quite insignificant when compared with that of the breccias. These intrusive bodies occur partly within the breccia, partly within the sedimentary strata and the crystalline schists beneath the breccia. They have the form of laccolites, intrusive sheets, dykes, and stocks, and embrace coarse-grained, medium-grained, and aphanitic rocks. Their relation to the andesitic breccias is clearly shown in most instances.

The largest of these intrusive bodies occur in the sedimentary strata of the Gallatin Mountains, south of Electric Peak.<sup>1</sup> One

<sup>1</sup> 'The Eruptive Rocks of Electric Peak, etc.' 12th Ann. Rep. U.S. Geol. Surv. p. 578, Washington, 1891.

forms a laccolite in Cambrian strata immediately over gneiss. Its volume was about  $1\frac{1}{4}$  cubic mile, and its silica content is 61 per cent. It is traversed by a second plug-like intrusion, whose volume was probably 2 cubic miles: the average silica content of this mass is about 70 per cent. A third body of intrusive rock is like the first in composition, having about 65 per cent. of silica. These are the oldest intrusions exposed in the Gallatin Mountains. The intrusive sheets connected with the last-mentioned bodies traverse Electric Peak and are older than the eruption of igneous rocks that rose through the conduit there and reached the surface as andesitic breccias, and filled dykes and the stock with porphyries and diorite. At this place the intrusive and extrusive series are directly connected, and the two groups correspond in the order of their eruption. The rocks flowing through the conduit appeared on the surface as hornblende-pyroxene-andesites cut by a dyke of basaltic andesite, and by more siliceous andesite-porphyries, ending in dacite: the intrusive series ranging from diorite to quartz-mica-diorite and granite. The volumes of these bodies are small, the cross-section of the core being about  $\frac{1}{2}$  square mile.

In the neighbourhood of Haystack Mountain, at the head of Boulder Creek, Montana, the sheets intruded into the Cambrian beds are acid andesitic porphyries, which appear to have been connected with the earliest eruptions of acid andesitic breccias. In the core of the Haystack volcano the intruded mass is gabbro-diorite, varying in different parts between these two varieties of rocks. It is cut by a few small dykes of more siliceous rock. The region about Emigrant Peak contains several large bodies of dacite and dacite-porphyry that burst up through the basic andesitic breccia. The superficial extent of these intrusive bodies approaches 40 square miles, and their volume was probably 20 cubic miles.

The core of the Crandall volcano consists of gabbro, passing into diorite, with a constantly increasing acidity, the last intrusions being granite.<sup>1</sup> The cross-section of this core is about  $1\frac{1}{2}$  square mile, and, if 10,000 feet deep, its volume was about 3 cubic miles. The most siliceous portions are relatively very small. The dykes which radiate from this core are mostly formed of rocks corresponding to gabbro in chemical composition, only a few correspond to the diorite, and none were found which were equivalent to the granite. Some, however, occur more basic than the gabbro, and there are complementary dykes of absarokite and banakite.<sup>2</sup> In the breccia in places are the lava-flows corresponding to these complementary dykes, but their volume is quite insignificant. There are similar occurrences of dykes and superficial lava-streams throughout the range of mountains to the south.

The eruptions of these intrusive rocks were contemporaneous with those of the andesitic breccias, in many instances, and occurred within the period during which the volcanic range was built. They have suffered erosion together with this range. The coarse-grained

<sup>1</sup> *Op. cit.* p. 609.

<sup>2</sup> Iddings, 'Absarokite-Shoshonite-Banakite Series,' *Journal of Geology*, vol. iii. (1895) no. 8.

gabbros and medium-grained diorites and granite solidified at considerable depths below the surface, and might very properly be classed as 'deep-seated' or 'abyssal rocks,' if we use that term. The laccolitic rocks are typical, and would seem to belong to what Prof. Brögger calls hypabyssal. But in this region the one kind are just as deeply seated as the other, and in some cases the laccolites are more deeply-seated than the coarse-grained rocks in the cores. So that for these intrusive rocks the terms 'abyssal' and 'hypabyssal,' if applied with any geological significance, would not fit groups of these rocks, which might be made to accord with textural differences. Moreover, while it is possible to consider the order of eruption of the intrusive rocks apart from that of the extrusive rocks, such a method would not seem a comprehensive one.

Leaving the discussion of this matter for the present, let us continue our review of the history of volcanic activity in the whole region. After the close of activity along the chain of andesitic volcanoes, denudation set in on a grand scale, and the lofty mountains were cut to pieces by the running waters that drained their slopes. A long time must have been consumed in reducing them to nearly their present configuration. How long this was we have no other means of judging than by considering the amount of this erosion, which reduced the height of the Crandall volcano some 10,000 feet.

When volcanic activity again broke out, its seat was shifted westward, and its character was changed; there were no longer scattered explosions from what was probably a line of faulting or fissures, but the gushing forth of gigantic floods of lava, whose composition was quite different from the bulk of those that built up the range of andesitic volcanoes. That this outflow must have been through some great fissure or set of fissures its volume and form, and its relation to the surrounding mountains, clearly attest. Moreover, we have in the fissure-eruption in Iceland in 1783 an indication of what took place in this region. The fissure in Iceland was 12 miles long, and the lava that poured out flowed in streams 45 and 50 miles long, in places forming lakes 12 and 15 miles wide, and 100 feet deep, and in a gorge 200 feet wide reaching a thickness of 600 feet. The total volume of the lava has been estimated as greater than that of Mont Blanc.<sup>1</sup>

Some idea of the flood that broke forth west of the volcanic chain in Wyoming may be gained by considering that its present extent is 50 miles from east to west, and from north to south it is exposed to view for 90 miles. But its south-western boundary is unknown, since it is covered by still more recent lava. Throughout this vast extent, more than 2000 square miles, it is an unbroken sheet, whose depth in the central portion is unknown, but is more than 1000 feet, and in some places more than 2000 feet. It forms the great plateau of the Yellowstone Park, and the region south-west of it

<sup>1</sup> Arch. Geikie, 'Text-book of Geology,' 3rd ed. 1893, p. 222.

in Idaho. In this direction it descends in a series of great terraces, and continues at lower altitudes for unknown distances down the broad plain which forms the valley of the Snake River. It has been followed for some distance down the channel of Falls River, which has cut through the capping of basalt, and extends along the western base of the Teton range to Pierre's Hole, where it underlies basalt.<sup>1</sup> And similar lava is exposed underlying the same basalt-sheet 150 miles to the south-west down the Snake River at Shoshone Falls.<sup>2</sup> No proper estimate of the volume of this rhyolitic lava can be made, but, judging from the area exposed, its volume is much more than 400 cubic miles.

This rhyolitic lava is quite uniform in its composition; the average silica-percentage is about 74. Its eruption may have occupied a long time, but evidences of repeated outbreaks are not numerous, and much of the lava belonged to single flows, since cañons 1000 feet deep cut through a continuous body of rock in most cases.

Closely connected with the eruptions of this rhyolite-lava were others of basalt. Not only is there no evidence of any extensive period of erosion separating the eruptions of one from that of the other, but streams of basalt immediately underlie the rhyolite in places, resting on the greatly eroded surface of the long-extinct volcanoes. Basalt-streams in rare instances lie between rhyolite in such a way as to prove their comparative contemporaneity. But the great bulk of the basalt poured out immediately after the rhyolite. Its eruption was also from fissures, still farther south-west and west. And the result was the flooding of all the great plain that stretches westward through Idaho along the line of the Snake River. The extent and thickness of this enormous sheet of basalt can only be guessed at, so little is known at present of its boundaries. That it is practically continuous as a covering for the country, and that it rests immediately upon the great rhyolite flood, are both well-established facts; also that it was the last great outburst of lava in this region, and closed the series of Tertiary eruptions in this part of the world. Its eruption undoubtedly took place from many fissures. Any estimate of its volume must be wide of the truth, but when we consider that the area of country known to be covered by it is much more than 300 miles long from east to west, and 50 to 60 miles wide, or more than 18,000 square miles, and when we consider what thicknesses have been observed in the cañon cut through it, an average thickness of 200 feet must be well within the limits of truth. With this thickness its volume is at least 700 cubic miles.

In this region, then, we have bodies of extrusive rock of great magnitude, to be reckoned in hundreds of cubic miles, and bodies of intrusive rock of much less magnitude, but of no mean propor-

<sup>1</sup> Bradley, F. H., Report in Hayden's 6th Annual Rep. U.S. Geol. Surv.

<sup>2</sup> King, C., U.S. Geol. Expl. 40th Parallel, vol. i. p. 592 (Systematic Territories, pp. 213-215, Washington, 1873. Geology), Washington, 1878.

tions, whose volumes may still be estimated in cubic miles. There are besides many bodies of comparatively small size, both extrusive and intrusive. To the first category belong the andesites of various kinds, rhyolites and basalts; to the second, the medium-grained and coarse-grained granular rocks and porphyries; while to the third belong any of these, and the exceptional varieties such as absarokites, shoshonites, and banakites. All are inseparable parts of the volcanic history of the region in Tertiary times, and their testimony as to the sequence of events is necessarily concordant. From it we learn that the earliest eruptions were of magmas which, as laccolites, became hornblende-mica-andesite-porphyry, and as extrusive rocks became hornblende-mica-andesite; with these magmas were associated hornblende-andesites and porphyries, and some that might be classed as dacite. Later there were great eruptions of magmas solidifying as pyroxene-andesites of several kinds, or as diorite, followed by those yielding andesitic basalt, and basalt or gabbro.

We find at one volcano, that of Electric Peak and Sepulchre Mountain, a succession of more and more siliceous magmas following those of diorite and pyroxene-andesite, reaching dacite. In the region of Emigrant Peak and Mill Creek numerous and large bodies of dacitic porphyry, or acid andesitic porphyry, traverse the basic andesitic breccia. At Crandall volcano there was first acid andesite, then basic andesite and andesitic basalt. Then in the core of the volcano we have a reversal of the series, after the basaltic magma had crystallized as gabbro, yielding diorite and granite in small volumes. But away from the core occur complementary basic dykes. In these volcanoes we find evidence of a quite local differentiation, yielding smaller volumes of magmas, becoming more and more extreme, and furnishing an aplite in the core, and at Crandall volcano the basic complements at a distance.

There is a repetition of this history in the extrusive breccias forming the southern half of the range. Then a long period of rest, followed by sudden and violent eruptions on a scale almost without parallel, producing two distinctly marked and contrasted types of magma, rhyolite and basalt, whose combination would reproduce a magma like that with which the first eruptions began. Furthermore, while they closed the period of activity, the compositions of these magmas are not so extreme as are those of some of the small bodies of magma that closed the eruptive activity centred about some of the great volcanoes just mentioned. If they represent the products of a differentiation, as I believe they do, the differentiation was not so extreme, or possibly not of the same kind, as that which took place at the base of one of the volcanoes.

In the assemblage of activities that occurred in Tertiary time in this region, there must have been processes of differentiation of different orders; some taking place in large reservoirs of magma, others affecting smaller ones, some in deeply-seated magmas, others in magmas nearer the earth's surface. The differentiation was undoubtedly due to a disturbance of the physical equilibrium previously existing between the molecular constituents of the magma,

the most natural causes for which disturbance seem to be changes of temperature, and possibly of pressure. And we should expect the most marked results where these changes were the greatest. We should expect to find the greatest changes for a given period of time experienced by magmas introduced into the cooler parts of the earth's crust; it being understood that differentiation will take place the more readily, the more liquid the magma; and take place, if at all, before the magma solidifies. We should then expect a differentiation in the most deeply-seated magma to progress the most slowly, other things being equal; and further that it would be less likely to reach such an extreme as that attained by a magma nearer the earth's surface. But the chemical nature of the original magma must have a marked influence on the results, and it seems to the writer that magmas richer in alkalies are more readily differentiated, and produce more extreme results.

The suggestion of Prof. Pirsson<sup>1</sup> that at a volcanic centre the hotter part, being at the centre of the reservoir, would be the *locus* of the more siliceous products of differentiation, while the cooler margin would contain the least siliceous products, has a direct bearing upon the order of succession of eruptions within the centre of a volcanic core, and is applicable to the Crandall volcano.

The elaboration of the processes of differentiation, and of the eruption of the resulting magmas, necessitates many considerations involving the size, position, and shape of the reservoir, and possible differences of temperature; the times of eruption, size, and shape of the conduit, and the laws controlling the flow of liquids. For, with varying viscosities in the several parts of a differentiated magma, the relative liquidity of the parts will influence the order of eruption according to the size of the conduit and the velocity of the flow. The operation of so many factors must prevent uniformity in the results of volcanic activity, but may permit numerous repetitions in different localities of closely analogous series of results.

If there be fundamental or primary as distinguished from subsidiary processes of differentiation, and if the former be considered to affect the most deeply-seated magmas, while the subsidiary processes take place in smaller reservoirs of magma nearer the surface—and if these processes find expression in the magnitude of the bodies of derived magma, and in the order of their eruption—then some idea of the relative order of those processes which gave rise to the many bodies of igneous rocks that constitute so great a feature in the geology of the region just described may be gained if we climb to the summit of a commanding peak in the Teton range and look about us over the surrounding country. Standing, as we may be, at an elevation of 13,000 feet above sea-level, and 7000 feet above broad valleys to the east and west, with the Teton Mountains descending rapidly below us to the north, we have an uninterrupted view of the region of volcanic activity. Directly east the remnants of the once lofty chain of andesitic volcanoes rise in a range of rugged mountains, sombre in the colour of their barren crests, which

<sup>1</sup> Pirsson, L. V., 'Complementary Rocks and Radial Dykes,' Am. Journ. Sci. ser. 3, vol. 1. (1895) pp. 116-121.

reach altitudes of 9000 and 12,000 feet. We are nearly opposite the southern end of the range, the nearest peaks being 40 miles off, and its breadth about 50 miles. As the eye follows the western front of the range northward, it gradually sinks behind the level-topped plateau, until only the higher peaks are visible. These may be traced westward across the northern boundary of the Yellowstone Park to Electric and Emigrant Peaks, beyond which our imagination alone can follow them to their northern end, 140 miles distant. Remembering how much of this range is extrusive rock, and trying to locate those spots where intruded stocks have been discovered, whose relations have been greatly magnified by the process of detailed study and description, we are impressed with their insignificance when compared quantitatively with the breccias in which they occur.

The great rhyolite-plateau, with its monotonous covering of pine forest, occupies the foreground northward, stretching from the base of the Teton Mountains to the north-east, north, and north-west, for distances of 50 and 70 miles, and descending in great terraces towards the valley of the Snake River. The whole 2000 square miles lies before us as a map, greatly foreshortened, with boundaries outlined by mountains on the east, north, and west. Turning our faces westward, we look down across the broad open valley of the Snake River, into which the western slopes of the Tetons gradually descend. The farther side is 100 miles away, and beyond our horizon this vast intermontane plain continues monotonously for hundreds of miles—all basalt.

Surely the depths at which these once molten floods of rhyolite and basalt were differentiated must have been profound, and the processes of their differentiation, when compared with those which produced the small bodies of magma in the conduits of the Electric Peak and of the Crandall volcanoes, must have been the more fundamental.

There are, then, in this region extrusive rocks, whose volumes are of such magnitude that the evidence drawn from the succession of their eruptions and from their composition is of a higher order than that derived from the lesser and more localized eruptions, whose volume, however, may be estimated in cubic miles. It is upon evidence of this order that I ventured to enunciate the principle, that in a region of eruptive activity the succession of eruptions commences in general with magmas representing a mean composition and ends with those of extreme composition.

#### PLATE XXIX.

Geological Sketch-map of portions of Idaho, Montana, and Wyoming, showing in part the distribution of the volcanic rocks; on the scale of 40 miles to 1 inch.

#### DISCUSSION.

Dr. H. J. JOHNSTON-LAVIS and Mr. J. J. H. TEALL spoke.

36. *The GEOLOGY of the EASTERN CORNER of ANGLESEY.* By EDWARD GREENLY, Esq., F.G.S. (Read June 10th, 1896.)

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## I. INTRODUCTION.

THE observations recorded in this paper were made during a detailed survey on the 6-inch scale, by myself, of a small portion of Anglesey. It is my intention to continue the mapping of the island on the same scale.

I should like to express my thanks to former workers upon Anglesey, all those with whom I have come into communication having expressed the warmest sympathy with my undertaking; and in particular to my former chief, Sir Archibald Geikie, and to Prof. Bonney, who have aided me very substantially by generous loans of slides and specimens.<sup>1</sup> My friend and late colleague, Mr. Peach, has also, with his wonted goodness, looked over the graptolites and other fossils for me. Dr. G. J. Hinde and Prof. T. Rupert Jones have been so kind as to determine certain small organisms; and to Mr. G. J. Williams I am indebted for the photograph of the slates at Careg Onen.

## II. CAREG ONEN SLATES.

The Carboniferous Limestone and Ordovician shales form the greater part of the cliffs about the cove of Careg Onen<sup>2</sup> (fig. 1), but near the western end of the beach we find, emerging from beneath the latter, a series of hard, greenish, fissile rocks dipping apparently at very high angles (figs. 1, 2 & 3). Careful examination, however, reveals indistinct planes of bedding, crossing the conspicuous divisional planes—which are really planes of cleavage—at various angles, and evidently much folded (fig. 4, p. 620). There are some lines of dark nodules following the bedding: some zones are gritty, and there are others of hard, compact argillite, scarcely cleaved, which contain a few oolitic grains.

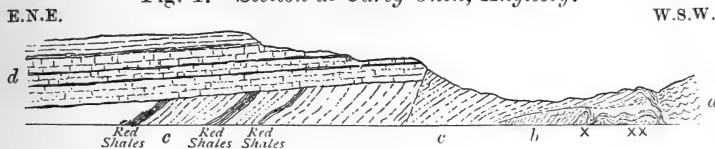
<sup>1</sup> I am preparing an Index of Anglesey Literature, which I hope to make exhaustive. In these pages, therefore, passing reference only will be made to the principal papers on the area.

<sup>2</sup> Careg Onen is the name of the cove about  $\frac{1}{2}$  mile north-west of Bwrdd Arthur. It has no name on any of the maps. This, and many other names desirable for reference, will, I hope, be soon inserted in new editions of the Ordnance maps.



At the base is a peculiar grit, a few inches thick, composed of quartz and detrital muscovite. Under the microscope certain round bodies are seen in it, of which Dr. Hinde writes:—‘The rounded bodies in the slide are undoubtedly sections of sponge-spicules, which are cut through some at right angles, others obliquely, and very rarely in the direction of their length. The dark spot in the centres of most of them is the axial canal of the spicule, now filled with some dark mineral. In some cases the spicules have

Fig. 1.—Section at Careg Onen, Anglesey.



[Horizontal and vertical scale : 1 inch = 440 feet.]

a = Schists.

b = Careg Onen Slates.

c = Ordovician Shales.

d = Carboniferous Limestone.

[The bedding of c should conform to their base-line throughout.]

Fig. 2.—Enlargement of x in fig. 1.

N.N.W.

S.S.E.

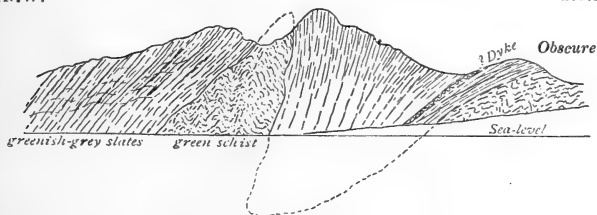


Fig. 3.—Enlargement of x x in fig. 1.

S.E.

N.W.



been squeezed out of shape. They are from .07 to .26 mm. in thickness. I cannot say to what group of siliceous sponges they may have belonged, for only these sections are to be seen. They are now of microcrystalline (?) silica of the same character as is usual with sponge-remains in Palæozoic rocks. They seem to be fairly numerous in the rock.' (See fig. 5, p. 620.)

The slate and argillite also contain micas, which often lie at right angles to the cleavage, and are bent. The nodules show no certain organic structures.

Near the western end of the section the schists rise suddenly from beneath these slates in a very sharp anticline (fig. 2), and disappear again before rising *en masse* to the west, where there is a sharp fold back, apparently torn out into a reversed fault thrusting the schists a little over from the west (fig. 3).

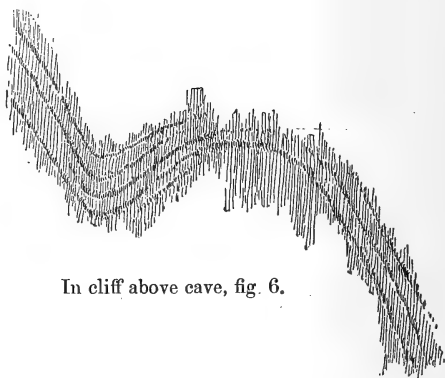
These slates are certainly unconformable to the green schists. Powerfully as they are folded, they are not in the least affected by the extreme and involved contortions of the schists, which are clearly seen to be truncated against their base. Their microscopic structures are also entirely different.

Again, the slates themselves appear to be, not a lower part of the Ordovician Series, but part of some older group separated from

Fig. 4.—*Folded bedding in pale green slates; fine gritty seams.*

N.N.W.

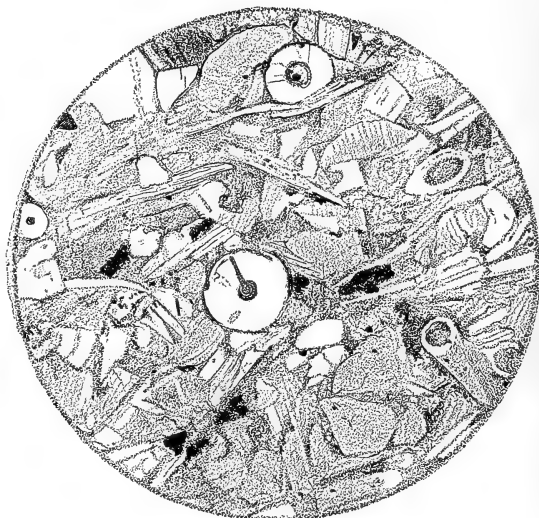
S.S.E.



In cliff above cave, fig. 6.

[About  $\frac{1}{2}$  natural size.]

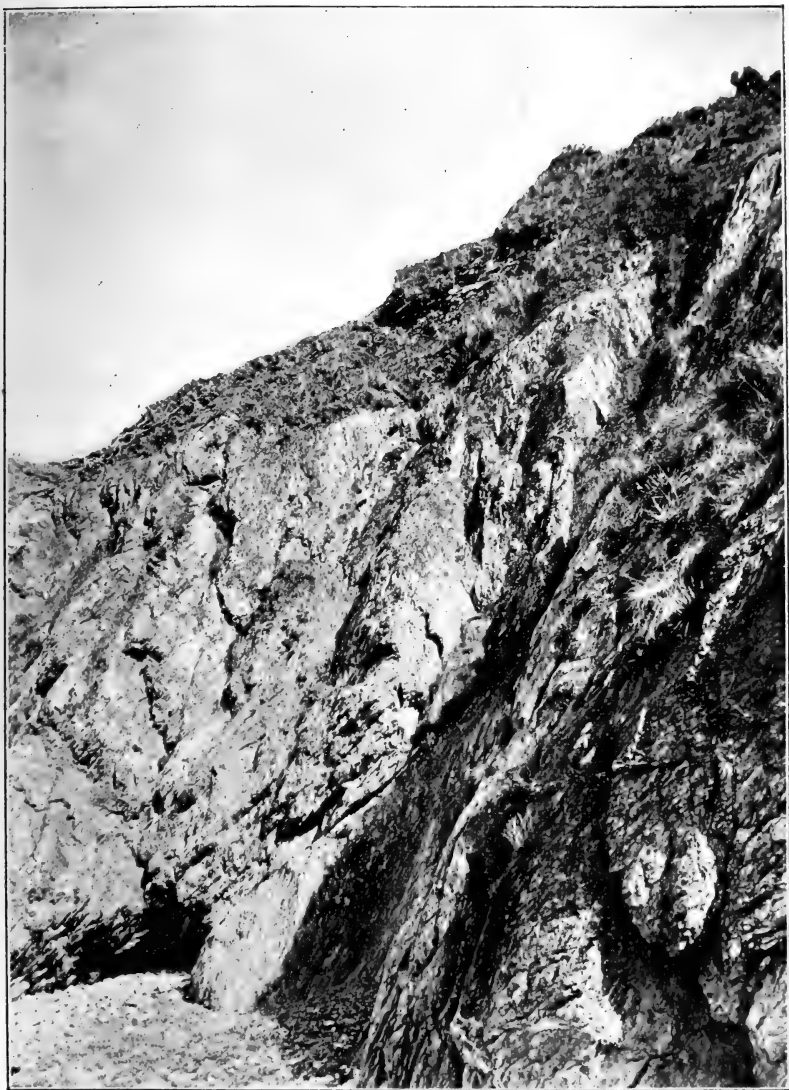
Fig. 5.—*Grit with sponge-spicules, Careg Onen.*



× 40.

that series by another unconformity. Indeed, I think that this junction, rather than that between the slates and schists, must be

Fig. 6.—*Slates underlying Ordovician shales at Careg Onen, Anglesey.*



*Note.*—The conspicuous divisional planes in the slates are cleavage, dipping N.N.W. at  $65^{\circ}$ – $85^{\circ}$ . The bedding, which is much folded (see fig. 4, p. 620), is not perceptible in this view. The Ordovician shales are seen at the top of the cliff, dipping N.E. at  $20^{\circ}$ – $30^{\circ}$ .

the unconformity noted by Mr. Selwyn (Ramsay, 'Geology of North Wales,' Geol. Surv. Mem. vol. iii. ed. 2, 1881, p. 223).

As seen from the beach (fig. 6, p. 621), the slates form a hard and well-marked feature (in which the sharp anticline of schist is included), over which pass the softer black shales, their bedding-planes dipping at very nearly the same angle as the top of the feature.<sup>1</sup> The discordance between their dip and the cleavage of the slates is most marked, the latter being nearly vertical. The strikes also are in different directions, the slates running E.N.E., and the shales at this point N.W. Moreover, though it is difficult to trace bedding for any distance in the slaty group, yet none of the beds, even when at high angles, pass up into the group above, or over the crest of the anticline, the schist rising nearly, if not quite, to the base of the dark shales. Most important of all, the cleavage of the green slates stops short at the base of the shales, which are quite uncleaved, even where seen, as at one place, actually in contact with the lower group.<sup>2</sup>

Now these shales are not hard or coarse beds which would resist a cleavage, but, it must be noted, are even finer and more susceptible of such a structure than the lower rocks which possess it in a high degree. Had the compression, therefore, operated at a post-Ordovician date, these dark shales could not have escaped, but would have received a cleavage readily, as even much coarser beds of that age have in the Caernarvonshire mountains.

The unconformity would seem, then, to be not merely local, but of systematic value. But if we have here a fragment of an older system, that system could not be later than Cambrian; and indeed, as no break so pronounced has been observed in North Wales between Ordovician and Cambrian, it would almost certainly be older still. The occurrence, therefore, of undoubted organic remains in these rocks is of great interest, as they would appear to be of pre-Cambrian age. Moreover, it would follow that the group of crystalline schists here seen must be assigned, both as regards their first formation and metamorphism, to a yet earlier period.

Experience has shown, however, that it is unwise to build too much upon the evidence of single sections, however decisive it may appear, especially when the rocks have been subjected to powerful earth-movements. There has been powerful movement here at two, if not three, distinct periods. Confirmation from other sections, or possibly from palæontological evidence, must therefore be looked for.

But unless such evidence contradict that which is seen here, it would seem that the crystalline schists of at least this region of Anglesey must be of extreme antiquity.

<sup>1</sup> The surface of the feature is marked by slickensides, which occur also in the schists; but the discordance cannot be due to movement of this kind. A false appearance of such movement has been produced in fig. 1 (p. 619) by my exaggerating somewhat the width of the anticline in the shales.

<sup>2</sup> Mr. G. J. Williams, F.G.S., kindly permits me to add that he concurs with me in this reading of the Careg Onen section.

## III. BARON HILL OR BANGOR GROUP.

The stratigraphical importance of this group has been generally admitted since the discovery of the classical section in the Baron Hill drive by Prof. Bonney (*Quart. Journ. Geol. Soc.* vol. xxxix. 1883, p. 470): nor has any doubt been thrown upon his identification of it with the volcanic group of Bangor. To his admirable petrological description there is little or nothing to add.

The stratigraphical relations of the Baron Hill outlier have, nevertheless, remained in some obscurity; and therefore certain points which have come out in the course of the mapping will be of some interest.

Prof. Bonney considered it probable that the junction was faulted. Prof. Blake describes (*Quart. Journ. Geol. Soc.* vol. xlv. 1888, p. 463) a visible unconformity at the south-western end of the drive section. The lowest rock seen there at present, however, is the ashy grit; nor is anything else exposed in some bosses below the drive at that point, which must be some feet lower down in the series. Further, I would draw attention to the following points.

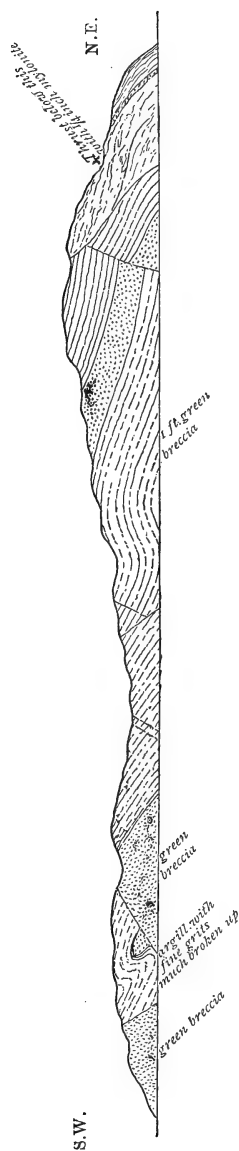
Prof. Bonney has remarked, with justice, upon the obscurity of the dips in the drive. The cuttings were then fresh, and probably the bedding has since become more distinct by weathering, though it is still inconspicuous. On careful examination a fine, even banding in the green argillites, with occasional sandy seams, can be seen, dipping steadily a few degrees W. of N. at angles varying from  $30^{\circ}$  to  $90^{\circ}$ , the average being high. Moreover, if any doubt remained as to the drive section, there can be none as regards some old weathered bosses along the top of the wood, where bedding with the same dip and strike is perfectly clear. The thickness, measured from these dips, would be not less than 1000 feet.

It will be seen that these planes strike almost directly at the N.E.-S.W. boundary (as well as at the strike of the adjoining schists); and if the structure be considered in relation to the form of the surface, it becomes evident that the outlier cannot be resting undisturbed upon the schists.

To explain this by normal faulting, however, would require very large faults, of which there is no evidence whatever on the coast to the S.W.; and which, moreover, the mapping of certain zones in the adjoining schists shows to be almost if not quite impossible, especially when the trend of the rock-features is considered. If there be any such faulting, it must, I think, be of small throw, and cannot extend all along the line. With regard to the E.S.E.-W.N.W. boundary, it is probable that there is a normal fault; but this must be a small one, as it does not appreciably displace a zone in the schists south-east of Murddyn Siglen. The northern boundary, however, is almost certainly a normal fault, running W.S.W.; of which there is evidence also in the featuring—a deep hollow in the hill-face, with a line of springs farther up.

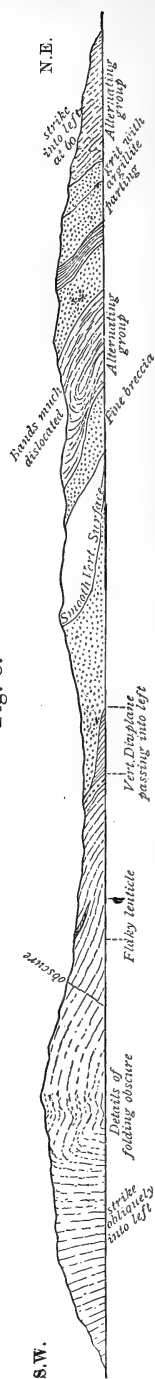
It appears, therefore, that the Baron Hill outlier must be bounded by and resting upon a plane of somewhat exceptional nature.

Fig. 7.—Sections in the Baron Hill Group.



Third Boss on the Drive (from the west).

Fig. 8.



Fourth Boss on the Drive.

[Horizontal and vertical scale : 1 inch = 50 feet.]

Unless the beds are rapidly folded in boat-shaped isoclinal folds whose axes are inclined nearly parallel to the slope of the surface, they cannot be resting upon their natural base. This, however, is unlikely from internal evidence. The sum of the evidence seems to be in favour of supposing that they lie upon a dislocation-surface inclined to the N.E. at an angle rather steeper than the slope of the ground. This would give the form of outcrop which actually exists.

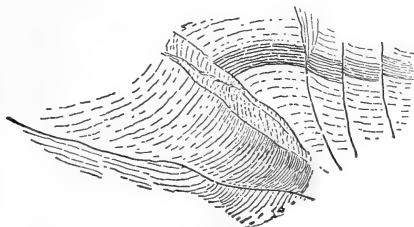
Turning now to the rocks seen in the drive, there is abundant evidence that they have been subjected to movement such as might be expected just above such a surface. They are, in fact, in the same broken condition as are those masses of Cambrian and Torridonian sediments which in the North-western Highlands are brought forward upon one of the major thrust-planes. The accompanying sections (figs. 7 & 8), on the scale of 50 feet to 1 inch, illustrate this. But they give no idea of the extent to which the fine argillites have been fractured. This is shown in fig. 9, which is taken from a spot  $2\frac{3}{4}$  inches below the thrust at the point  $\times$  in fig. 7. Further, along this very thrust-plane is a seam of material up to  $\frac{1}{4}$  inch thick, resembling in every way the mylonites of the Highland thrust-planes. The same phenomenon is seen in several places. It was difficult to obtain material for slicing without defacing the surfaces (I hope that the section ' $\times$ ' will be respected); and slices have therefore been cut from specimens showing similar structure in the Tairfynnon Breccia near Bangor, which it was surprising and interesting to find. These show, under the microscope, perfectly typical mylonitic structures (fig. 10, p. 626).

The direction of movement is manifestly from right to left in the figures, but as these are not taken along the full dip, but along the crag-faces, it is probably from north-east or east.

With regard to relative age, the contrast of metamorphic condition between these rocks and the schists, on which stress is laid by Prof. Bonney, remains, I think, unaltered; though perhaps caution may be necessary in view of movements of the nature here described. If, however, as certainly seems most probable, these rocks are later than the adjoining schists, it is obvious that the overthrust supposed must be thrusting higher beds upon lower, a reverse of the usual effect. This, however, would follow if the angle of thrust were less than the dip of the beds.

The evidence here given would lead us to expect that a zone of

Fig. 9.—Face of cliff,  $2\frac{3}{4}$  inches below the thrust shown at  $\times$ , fig. 7.



Green banded argillite. Natural size.

complicated structures, now concealed beneath the Carboniferous Limestone, may underlie the old rocks of Bangor and Caernarvon.<sup>1</sup>

Fig. 10.—*Mylonitic seam in Tairfynnon Breccia.*



× 35.

#### IV. ORDOVICIAN SERIES.

The rocks of this age which fall within the district under consideration are almost entirely covered by Boulder Clay, and, towards the northern end, nearly,<sup>2</sup> though not quite, overlapped by the Carboniferous Limestone.

The best section is that on the coast at Careg Onen, where about 700 feet of black shale, with a few red bands, are seen (fig. 1, p. 619).

These have yielded a shell like *Obolella*, and a fragment of a trilobite (undetermined), as well as the fossils found by Prof. Hughes (Proc. Camb. Phil. Soc. vol. iii. pt. viii. p. 347); and inland, in some mudstones west of Bryn Poeth, I found some fragments apparently of phyllopoda.

The occurrence of a bed of pisolitic ironstone is alluded to by Ramsay ('Geology of North Wales,' p. 223). It does not occur at Careg Onen,<sup>3</sup> but as, from evidence to be given below (see p. 628,

<sup>1</sup> I am unable to confirm the occurrence of another outlier of this group near Llanddona (Quart. Journ. Geol. Soc. vol. xlv. 1888, p. 465, and appended map): the rocks belonging, in my opinion, to the schistose complex.

<sup>2</sup> Their western boundary, which has been moved about  $\frac{1}{2}$  mile westward in a recent map, was correctly drawn by the Geological Survey.

<sup>3</sup> I do not think that the ironstone which there overlies the schists can be the same. It has not the same character, is only 6 inches thick, and its associated rocks are quite different.



'*Llanddona*'), it is clearly not dying out in that direction, it is probably cut out by the fault which throws down the Carboniferous rocks, and if so, the beds with the trilobite and *Obolella* must be below it. The obscure fossils hitherto found may quite well be Arenig forms, and therefore only the upper part of the shale-series can be upon any higher horizon.

An interesting point remains to be noted concerning the rocks among which the pisolitic ironstone lies at Bryn Poeth (fig. 11).

These are not ordinary grits and shales, but bedded felspar-tuffs of varying texture, mixed with some sandy and muddy sediment. They are quite uncleaved. The finer bands approach very nearly to shales, but the coarser (fig. 12) are chiefly composed of broken lath-shaped felspars, most of them quite angular, and many even with re-entering angles, about  $\frac{1}{10}$  inch in length. They are often wonderfully fresh and beautifully twinned. The

Fig. 11.—*Bryn Poeth Quarry.*  
*Section at the northern end.*

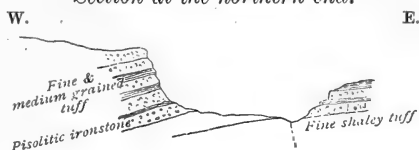


Fig. 12.—*Felspar-tuff below pisolitic ironstone, Bryn Poeth.*



× 35.

matrix is dark, partly green by transmitted light, like that of the pisolitic ironstone, and contains also angular fragments of dark shale and andesitic lava, with generally a few pisolitic grains.

The pisolitic ironstone itself also contains a few lath-shaped feldspars. Though gradations exist, it does not pass imperceptibly into the tuffs, but occurs in a well-defined bed about 18 feet thick.

The section is a little obscured by small faulting, but there appear to be tuffs above and below. The whole series is about 50 feet thick, and probably lies in a gentle synclinal fold.

It is clear, therefore, that we have here a record of a volcanic episode contemporaneous with the latter part of the great Arenig eruptions of Merionethshire. And it would seem to be due to a separate outburst in this region, and not merely wind-borne from the south, otherwise the pisolite and shale could hardly be so free as they are from volcanic material.

(I may add that, in the *Didymograptus*-beds at Caernarvon, I found beds of very similar tuff, lying as hard ribs among the dark shales at Pont Seiont. I have failed to find any, however, in the shore-section east of Port Penrhyn at Bangor.)

There is no perceptible cleavage, but there has been powerful earth-movement, the shales at Careg Onen folding over, and plunging against the schists of the western end of the section.

*Llanddona*.—A tract of Ordovician shales must exist, almost entirely concealed by Boulder Clay, skirting the coast for about  $\frac{1}{2}$  mile on either side of Llanddona Church, and extending about  $\frac{1}{3}$  mile inland.

While mapping the drift-covered slopes I observed a great number of blocks of black mudstone, along with which were also many of pisolitic ironstone, and the drift itself was full of small angular fragments of black shale. At last two small exposures of shale, like that of Careg Onen, were found at Corn-ud. They dip W.S.W. at 25°, and are probably faulted against the schists.

I think it is safe to assume that this area is occupied by such shales (its featuring, moreover, is quite unlike that of the schists), and have therefore inserted it on the maps.

One or two of the boulders have yielded graptolites—‘*Climacograptus*, of a type that occurs in the Llandeilo-Caradoc rocks,’ Mr. Peach writes, adding that he ‘should think they belong to *C. bicornis*, but, without seeing their proximal ends, would not like to say anything further.’

## V. THE CARBONIFEROUS ROCKS.

These rocks are noticed briefly in Ramsay’s ‘Geology of North Wales,’ pp. 258–59. They present some points of general interest.

The prevailing type is a light grey, rather crystalline limestone; but there are many interesting varieties, particularly a thick mass of brown dolomite with pyrites and other heavy minerals.

Most striking, however, are the sandstones and conglomerates which occur near the East Point, and at Seiriol and Fedw Fawr, near the middle of the area. They are about 90 or 100 feet thick, and consist chiefly of very fine white sandstone, with pyrites and carbonaceous particles, and partings of soft grey shale. Obscure

plant-remains abound. At their base is a strong conglomerate about 20 feet thick, composed of vein-quartz pebbles with many of red jasper and green schist, as well as of limestone with Carboniferous fossils. Another conglomerate, less persistent, occurs higher up in the group. So far as faulting, which near the East Point is very frequent, permits one to judge, these groups of Seiriol and Trwyn-du appear to be on the same horizon (a thin conglomerate near Llangoed is much lower down); though perhaps not accurately so, as in certain sections pebbles and sand can be seen to come in on the same horizon as pure limestone.

Dark shales occur at all horizons, but are generally very thin. One of the thickest (about 6 feet) contains some small ostracoda. Prof. T. Rupert Jones refers them, doubtfully, to a small ovate form, probably *Leperditia acuta*, adding, however, that if a feature suggestive of a ventral rim or margin be really such, he would be unable at present to determine the specimens definitely.

The thickness of the whole series appears to be about 700 feet. 'Brecciation' is not uncommon in some of the limestones, quite unconnected with faulting, and appears to be really an early stage of dolomitization, the change proceeding along the cracks.

The unconformable relation to the underlying Ordovician Shales is well seen at Careg Onen (fig. 1, p. 619). The lowest beds seen—about 20 feet from the base—are dark limestone with shaly partings, and there is no sign of a conglomerate.

*Dykes.*—Three dykes mapped in the Baron Hill Rocks show a matrix exactly resembling, under the hand-lens, that of the andesitic dykes described by Mr. Harker (Geol. Mag. 1887, p. 409), with which also they agree in trend and general relations. There is no reason to separate them from that group, arguments for whose Carboniferous or post-Carboniferous age have been given by previous writers. A good many have been already mapped in the schists to the west, but their relations—which are interesting—will not be dwelt on in this paper. The dyke noted by Prof. Bonney (I trust, with him, that the ice-worn surfaces will be scrupulously respected) is quite thin, about 2 feet wide. The optical characters of its porphyritic crystals indicate a felspar allied to labradorite. There is also a dyke, about 12 feet wide, cutting the lowest boss of ashy grit in the drive.

## VI. GLACIATION.

### (a) *Striation.*

Striæ are rare, except on the Carboniferous coast-line where the drift has been but recently removed.

The prevailing direction is S.S.W., or a few degrees W. of S., except in a district lying east of a line drawn from Dinmor Point to Trwyn Penrhyn, in which there is cross-hatching with a series running S.S.E. Where they can be compared, the S.S.W. series can be seen to be the later.

Local deflections through as much as  $40^{\circ}$  may be observed on rock-faces no more than 3 feet high.

There are large glacial furrows in a few places.

Rock-bosses are generally moutonnés, on the N.N.E. side.

(b) *Drifts.*

The drift is for the most part a typical, tough, brown Boulder Clay, full of well-striated stones.

It is very thick in the Vale of Llanfaes, probably not far from 100 feet, fine sections being seen on the coast between Penmon and Beaumaris (Ramsay, *op. cit.* pp. 275-76). There is none on the Carboniferous escarpment, but it thickens gradually on the dip-slope, where there is one valley buried to a depth of 60 feet. The brow formed by the schists is also free from drift, which, however, again begins to fill hollows in the plateau to the westward.

A great thickness of Boulder Clay comes in again near Llanddona Church, where it forms cliffs about 50 feet high. Below Ffynnon-oer this Boulder Clay suddenly rises to the 200-foot contour, forming an inland cliff which must nearly follow a concealed rock-feature. There has been much land-slipping here, probably upon buried Ordovician shales.

Such boulders as can be identified with local rocks have travelled S.W.-S.S.W., a direction agreeing with that of the striæ. Boulders from the Welsh mountains have only been observed at Penmon; but rocks foreign to North Wales are abundant.

The gravels associated with the drift along the Lleiniog shore have been described by Ramsay, who notes their semi-consolidated state. They contain faintly-striated stones. Similar gravels occur at Llanddona.

About Llanfaes there is a singular stoneless (or nearly stoneless) red clay, as much as 10 feet thick. Its relations are not exposed.

These phenomena seem to me to be best explained by the theory of a confluence of bodies of glacier-ice coming from the north and from the Caernarvonshire mountains respectively. Not only does it explain the general south-westerly deflection of the striæ and boulders, but I think that the cross-hatching in the Penmon area can also be understood by means of it. In that area complications must have occurred. The influence of the great Ogwen glacier must have been much less than it was farther west, and the glaciers of Aber and Llanfairfechan only would have opposed the northern ice. On comparing the extent and height of their catchment-basins I doubt whether their combined force would amount to more than a quarter of that of the Ogwen glacier. That they did offer opposition is clear, for they extended at times as far as Penmon. But fluctuation in the masses of the northern and southern streams would enable the larger stream to pass on undeflected, especially if some fluctuations did not affect both at once, which might well happen—as their sources were so far apart. The local influence of some high ground at Dinmor Point (west of which, moreover, there is an

extreme deflection to W.S.W.) would then come into play, and cause the S.S.E. deflection. Moreover, the Llanfairfechan glacier, being the feeblest, would be the first withdrawn, and the Aber glacier would then rather aid the S.S.E. deflection than otherwise.

## VII. SUMMARY.

The south-eastern promontory of Anglesey consists chiefly (besides the schists) of Ordovician and Carboniferous rocks, overlain by extensive Glacial deposits; but there are also two small but important fragments of ancient formations at Careg Onen and Baron Hill.

The slates of Careg Onen rest unconformably upon the schists, and appear to be separated by another strong unconformity from the Ordovician shales. Whence it would appear, pending confirmation from other sections or direct fossil evidence, that the slates (which contain sponge-spicules) must be of pre-Cambrian age, and the schists themselves even older.

The ashy grits and bedded tuffs of Baron Hill appear to have been moved somewhat from the N.E. along a plane of overthrust. They are traversed by planes of mylonization, as well as isoclinally folded, and in general much broken up.

The Ordovician rocks consist chiefly of dark shales and mudstones, sparingly fossiliferous, but contain a group of volcanic tuffs on the horizon of the pisolitic ironstone. Another tract of Arenig beds, with the pisolitic ironstone and graptolitic shales, lies concealed beneath glacial drift at Llanddona.

The Carboniferous rocks appear to be about 700 feet thick. They contain 100 feet of conglomerates, sandstones, and shales, with plant-remains, about the middle of the series.

The glacial striæ sweep round from S.S.W. at the northern to S.W. and W.S.W. at the southern end of the district. In the Penmon area there is cross-hatching with a series running S.S.E., and it is suggested that this is due to fluctuation in the power of the Caernarvonshire glaciers to deflect the ice coming from the north, combined with the local influence of certain high ground.

## DISCUSSION.

Sir ARCHIBALD GEIKIE rose, not for the purpose of criticism, but to congratulate the Society on the acquisition of a geological recruit who, possessing leisure, enthusiasm, and capacity, was likely to advance the progress of geology in this country. Notwithstanding all that had been written regarding the geology of Anglesey, the subject still bristled with difficulties. Unsolved problems presented themselves in every part of the island. These could never be settled by mere hurried holiday visits, but needed such patient investigation as was demanded in the preparation of a geological map of the district on a large scale. The present paper, and the little piece of

mapping which accompanied it, were no doubt an earnest of what might be expected from the Author, who would carry into his labour the habits of minute and accurate observation which had distinguished his field-work when he was a member of the staff of the Geological Survey.

The PRESIDENT said that he was pleased to find that Mr. Greenly had undertaken to work out, with so much care, the geology of Anglesey. There were many important points in connexion with the crystalline schists and the overlying rocks which needed elucidation; but he was glad to find that the Author agreed with the speaker and others that the crystalline schists were of pre-Cambrian age and overlain unconformably by the Palæozoic rocks.

Prof. G. A. J. COLE congratulated the Author on picking up the history of Welsh vulcanicity in Anglesey, and on the discovery of a volcanic deposit on the horizon of the pisolitic ironstone, in addition to the more conspicuous and better-known areas of Cader Idris and Rhobell-fawr. He also compared the conglomerates containing blocks of the contemporaneous Carboniferous beds with those on the opposite Irish coast north of Rush, which occur along the junction of the Carboniferous Limestone and the old Ordovician shore.

The AUTHOR expressed his thanks to the Society for the manner in which the paper had been received.

37. *On FOLIATED GRANITES and their RELATIONS to the CRYSTALLINE SCHISTS in EASTERN SUTHERLAND.* By J. HORNE, Esq., F.R.S.E., F.G.S., of H.M. Geological Survey of Scotland, and E. GREENLY, Esq., F.G.S., formerly of H.M. Geological Survey. (Communicated by permission of the Director-General of H.M. Geological Survey. Read June 10th, 1896.)

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## I. INTRODUCTION.

THE detailed mapping of the eastern portion of the County of Sutherland by the Geological Survey has shown that the crystalline schists of that region are extensively penetrated by granites, more or less foliated, which are apparently linked to some extent with the present crystalline characters of these schists. Some of the features presented by these foliated granites have already been described by previous observers.

In 1862 Prof. Harkness remarked that the mode of occurrence of the granites in the east of Sutherland rather tends to the conclusion that the sedimentary rocks were elevated, flexured, and contorted previous to the period when the granites made their appearance in the sedimentary rocks, and that these granites have conformed in their course to the strike of the previously elevated strata. He further observes that here are abundant features which would support the conclusion that granite is in this district rather the result of an excessive amount of metamorphic action than a plutonic rock as regards its origin.<sup>1</sup>

In 1869 the Rev. Dr. Joass stated that he was inclined to regard the granites in the Kildonan region as partly intrusive and partly metamorphic. He further noted that in the most richly auriferous localities certain granitoid rocks, chiefly felspathic, are so intimately connected by interlamination with the flaggy quartzose strata that they almost appear to be the result of metamorphic action upon true sedimentary rocks of the quartzose series, or contemporaneous effusions of plutonic rock. This granitiform rock appears at least in one instance to run across the strike of the decomposed gneissose strata.<sup>2</sup>

<sup>1</sup> 'On the Metamorphic Rocks of the Banffshire Coast, the Scarabins, and a Portion of East Sutherland,' Quart. Journ. Geol. Soc. vol. xviii. p. 331.

<sup>2</sup> 'Notes on the Sutherland Goldfield,' Quart. Journ. Geol. Soc. vol. xxv. p. 317.

The minute penetration of gneiss, schists and sedimentary deposits altered by contact-metamorphism, by granitic materials in the form of excessively thin folia along the planes of schistosity was first clearly described by Michel-Lévy. In his paper 'Sur l'Origine des Terrains Cristallins Primitifs' he makes the following observations: 'J'ai, le premier, appelé l'attention sur le phénomène de pénétration intime, lit par lit, des roches granitiques et granulitiques éruptives suivant les plans de schistosité des gneiss et des schistes . . . Mais en outre, dans les zones de contact immédiat sur la roche éruptive, le quartz et les feldspaths s'insinuent, lit par lit, entre les feuillettes des schistes micacés; on est parti d'un schiste argileux détritique, on le trouve en définitive transformé en un gneiss récent, bien difficile à distinguer des gneiss anciens.'<sup>1</sup>

In 1890 Miss Gardiner described some of the contact-phenomena produced by the granite near New Galloway, and showed how the Silurian sediments pass into crystalline schists and gneiss with various contact-minerals at the granite-junction.<sup>2</sup>

In the same year, while referring to the gneisses of central Aberdeenshire, our colleague Mr. Hinxman states that the granitoid character of the gneiss at certain points is due to the intrusion of granitic material along the planes of foliation.<sup>3</sup>

In 1893 our colleague Mr. Barrow described in detail the metamorphism produced by an intrusion of muscovite-biotite-gneiss in the South-eastern Highlands. He showed that the normal condition of the intrusive rock is that of a slightly foliated granite with two micas, but with considerable variation as regards structure and composition, the larger masses being more or less fringed with pegmatite. The foliation of the larger masses is rudely parallel to that of the surrounding schists, and though their intrusive nature is therefore not so obvious, it has been proved by detailed mapping that these masses traverse different bands of the schists. The crystalline gneisses and schists with the contact-minerals, sillimanite, cyanite, and staurolite, arranged in zones according to the stages of metamorphism, are held to be due to the intrusion of muscovite-biotite-gneiss.<sup>4</sup>

In 1890 the Geological Survey first broke ground in the east of Sutherland from Melvich as a centre: the coast-line between Strath Halladale and Armadale having been assigned to Mr. Greenly. On the shore at Portskerry he observed minute granitoid folia radiating from the larger granite masses and traversing the granite-like schists. Mr. B. N. Peach mapped the larger sills of acid igneous rock in Strath Halladale and clearly recognized their intrusive character, ascribing the foliation of the granite to dynamic action. In the

<sup>1</sup> Bull. Soc. Géol. France, ser. 3, vol. xvi. (1888) pp. 104, 107.

<sup>2</sup> 'Contact-Alteration near New Galloway,' Quart. Journ. Geol. Soc. vol. xlyi. p. 569.

<sup>3</sup> Geol. Surv. Scotl. Explanation of Sheet 76, p. 12.

<sup>4</sup> 'On an Intrusion of Muscovite-biotite-gneiss in the South-eastern Highlands of Scotland and its Accompanying Metamorphism,' Quart. Journ. Geol. Soc. vol. xlix. p. 330.



same year (1890) Mr. Horne obtained confirmatory evidence of the 'lit par lit' introduction of granitic materials into the crystalline schists south-west of Strath Halladale. In the autumn of 1891 and 1892 Mr. Horne surveyed the coast-section between Kirktonny and Armadale and the tract extending south-eastward towards the Armadale burn, where there is a group of complex gneisses formed by alternating folia of granitoid materials and granulitic or coarsely granulitic gneisses or schists, recalling some of the Lewisian types between Cape Wrath and Laxford. These phenomena, which seem to have been developed at a later date than granulitic schists of the 'Moine' type, were briefly summarized in the Annual Report of the Geological Survey for 1892.

From the northern coast of Sutherland these intrusive granite-masses and pegmatites have been traced across the county by Forsinard, Kinbrace, and Kildonan to the Ord, Helmsdale, and Upper Strath Brora: Mr. Greenly having mapped the Kinbrace and Kildonan area, and our late colleague, Mr. Hugh Miller, the tract between the Ord and Upper Strath Brora. During 1893-94 Mr. Hugh Miller observed the phenomena resulting from the minute penetration of the eastern schists by granite on an extensive scale in the outlying parts of Rogart and Clyne. His observations in Upper Strath Brora led him to the following conclusions. The structures in the granites and granitic gneisses were supposed by him to be 'to a large extent imitation-structures, due to a simulation of the form and structural features of the country rock (the eastern schist) by granites that have by some means crept into their place. The process by which this replacement has been effected seems to have been a development of crystalline matter among the granulitic materials of the pre-existing schists and quartzites. In the earlier stages of metamorphism the granitic substance has entered or by some means suffused the structure of the stone, appearing first as a fine mottling of granitic particles. In further stages of metamorphism the granitic matter, keeping for the most part to the folia of the pre-existing rock, has increased into knots and knotty strings, has entered planes, slide-planes, and the lines of contortion in the contorted schists, and so thickens into bands and sills at the expense of the original rock, till the latter is represented only by inclusion-planes and ultimately by inclusion-structures. The crystalline matter of the granitic gneisses and granites remains optically complete, and the inclusion-structures and the inclusion-planes everywhere retain the same dip and strike as that of the country rock, not only in Upper Strath Brora, but also in Rogart and wherever present in the granite massifs of Helmsdale and the Ord of Caithness. Parts of these granites are in fact pseudomorphs or granite-casts preserving as replacement-structures remains of the structure of the pre-existing rock.'

## II. KIRKTOMY TO ARMADALE.

The various types of crystalline schists with which the granitic rocks are associated in this area may be grouped as follows :—

1. Granulitic schists or gneiss.
2. Biotite-schists and gneiss.
3. Granular gneiss.
4. Hornblende-gneiss or schist.
5. Cipolin group (crystalline limestones containing silicates).

The members of the first two groups display in a remarkable degree the introduction of granitic materials in the form of granitoid folia; thus giving rise to a series of complex gneisses, composed partly of granulitic and partly of granitic constituents. The evidence in the area between Kirkatomy and Armadale seems to point to the conclusion that these constructive processes operated after the formation of certain granulitic schists allied to the type of the 'Moine' schists, and yet the series of complex gneisses recalls some of the features of the Lewisian gneiss between Cape Wrath and Laxford.

The granite occurs in the form of branching sills, veins, and minute folia, penetrating the schists and gneiss along the planes of foliation, and in places it merges into massive pegmatite. It is usually foliated, the foliation being parallel to that of the schists, though in some instances it is clearly transgressive.

The essential constituents of the granitoid rocks are orthoclase, oligoclase, quartz, and biotite. A specimen of gneissose granite, taken from the shore at the edge of the outlier of Old Red Sandstone,  $\frac{1}{2}$  mile north of Kirkatomy, shows under the microscope orthoclase, oligoclase, quartz, and biotite, with apatite and zircon as accessories.<sup>1</sup> Both feldspars occur as allotriomorphic grains, but there are occasional signs that oligoclase may be idiomorphic with respect to an untwinned feldspar which is presumably orthoclase. Here and there indications of a micropegmatitic intergrowth of quartz and feldspar may be observed. The biotite does not occur as a rule in the form of detached plates, but usually in aggregates of several individuals which mutually interfere with each other. In a specimen of granitoid gneiss between Kirkatomy Point and Geodh na Muice muscovite occurs, though not in any great abundance, together with biotite, orthoclase, oligoclase, and quartz. These foliated granites and granitic gneisses are well displayed in the massive form between Kirkatomy Point and Pollsain, about  $\frac{1}{2}$  mile east of the headland.

The granitoid folia, alternating with folia of granulitic schists and biotite-gneiss, may be studied near Kirkatomy Point and about a mile to the east near Poulouriscaig. Their constituents resemble those of the larger veins and sills, with the exception that biotite

<sup>1</sup> Microscopic sections of rocks from the Kirkatomy area have been examined by Mr. J. J. H. Teall, M.A., F.R.S., who supplied notes on the various rock-specimens and sections.

is sparingly developed. They contain orthoclase, oligoclase, quartz, and occasionally biotite. Indeed, the remarkable feature of the granitoid rocks as a whole, both in the case of the larger masses and in the granitoid folia, is the abundance of oligoclase. A specimen taken from a locality about 100 yards from the edge of the cliff S.S.E. of Kirkatomy Point, in which the granite-bands can be seen cutting across the folia of the darker granulitic rock, shows under the microscope that the granitic bands consist of quartz, oligoclase, and orthoclase, with garnet and apatite as accessories. So minute are these layers of granitic materials that in some instances they do not exceed  $\frac{1}{4}$  inch in breadth: and hence in a specimen, say a foot across, there may be several granitoid bands alternating with layers rich in biotite or with granulitic bands containing quartz, felspar, and mica. It is further observable that the granitoid folia follow the various folds, and even the minute puckerings of the biotite-gneiss and the granulitic gneiss, without any apparent crushing or deformation of the constituents. The size of the grains does not vary with reference to the margin of the band, and there is no trace of chilled margins. Still more noteworthy is the fact that along the junction-line separating the granitoid from the other folia the minerals interlock just as they do in the interior of the different folia.

It is obvious that these phenomena do not resemble those of an igneous rock penetrating pre-existing strata along cracks and fissures where chilled margins may be readily detected. Indeed, an unbiased observer would almost infer at first sight that the granitoid bands are not in reality later than the gneisses and schists which they traverse. But in many excellent sections the quartzo-felspathic folia, which are identical in structure and composition with the quartzo-felspathic portions of the larger granite-masses, can be seen branching from the latter and following the contorted foliation-planes of the pre-existing strata. It seems reasonable to infer, therefore, that these igneous materials were introduced when earth-movements were in progress and when the pre-existing rocks were at a high temperature.

Throughout the area, numerous lenticles of granulitic schist occur as isolated masses in the foliated granite, the foliation of the schist being parallel to that of the granite. An excellent example is met with on the shore south of Uamh Dhom near Pollsain, east of Kirkatomy Point. Here small lenticles of highly siliceous schist of the 'Moine' type occur, with the planes of schistosity parallel to that of the granite. This instance further shows minute granitoid folia branching from the main mass and traversing the foliation-planes of the inclusions of granulitic gneiss. Under the microscope this siliceous schist or gneiss is composed of quartz, felspar, and biotite, with garnet as an accessory. Some of the quartz occurs as irregular patches.

In the belt of garnetiferous biotite-schist or gneiss extending southward from Kirkatomy Bay to Creag Meadie, foliated granite and pegmatite occur as lenticular masses varying from a few feet

to several yards or more in length. Their constituents resemble those of the larger veins and sills already described. Immediately to the west Mr. Peach has traced a great series of thin sills of foliated granite traversing the biotite-schist and granulitic gneiss.

Where the granitoid rocks traverse the biotite-schist or gneiss on the moor about 2 miles south of Armadale, the contact-mineral sillimanite was observed in the latter, associated with the biotite. This mineral was likewise found in an inclusion of biotite-gneiss in a granite-vein. The occurrence of the quartz in the biotite-gneisses in large, almost ophitic patches may also point to contact-metamorphism—if we may judge from an instance of the change produced in siliceous gneiss at the point of contact with an intrusive mass of augite-biotite-diorite at Sandside, Reay, in Caithness.

The foliated granite and the complex of gneisses between Kirkatomy and Armadale are traversed by veins of pink microgranite, which, so far as observation goes, are never foliated. These veins probably represent the last phase of igneous activity, which culminated in the introduction of the broad sills of foliated granite.

Reference may now be made to some of the other groups of crystalline schists represented in the area under consideration.

Group 4, composed of hornblende-gneiss or schist, is likewise traversed by gneissoid granite and pegmatite. It occurs in lenticular bands or masses, which are represented on the eastern side of Kirkatomy Bay, and on the moor to the south-east. A specimen from the eastern cliff of Geodh Acrah,  $\frac{1}{2}$  mile north of Kirkatomy, examined under the microscope by Mr. Teall, shows felspar, mostly striated, quartz, and green hornblende, with biotite and sphene as accessories. The three principal constituents occur for the most part as allotriomorphic grains. Now and then the quartz appears to form inclusions in the felspar and hornblende. The microstructure is granitic, not granulitic. Mr. Teall adds that there is no doubt a close resemblance between this rock and basic portions of the Lewisian Gneiss occurring between Laxford and Cape Wrath.

The granular gneiss (group 3), which extends from Armadale Bay westward for a distance of  $\frac{3}{4}$  mile, is a rather fine-grained granular rock, containing quartz, felspar (including oligoclase), biotite, and sometimes hornblende. This group is associated with highly quartzose schists or gneiss, with magnetite in well-formed octahedra.

The Cipolin group (no. 5) is in some respects the most interesting of this series. The rocks included in this group are exposed in a burn draining into the sea, about  $\frac{3}{4}$  mile W.N.W. of the village of Armadale. In the lower part of its course, where it flows through a rocky gorge, a band of crystalline limestone is exposed at the base of the cliff. One specimen from this locality has been named by Mr. Teall a banded cipolin, one band being mainly composed of crystalline calcite. Under the microscope it shows scapolite, calcite, quartz, a pale green pyroxene, and sphene. Scapolite is the most abundant mineral in that portion of the rock from which the

section is taken. The principal constituents occur in allotriomorphic grains.

The crystalline limestone is associated with a green crystalline granular rock, composed mainly of allotriomorphic grains of pale green pyroxene (omphacite), with altered scapolite, sphene, and pyrite. Along the strike of these rocks, on the sea-cliff at the mouth of the stream, flaggy hornblende-schist with omphacite is exposed; and in the walls of the gorge flaggy biotite-gneiss occurs with felspar (including oligoclase), quartz, and biotite. Apatite, zircon, and garnet appear as accessories. The foregoing series is pierced by veins of pink microgranite and pegmatite.

While in the foregoing pages we have adduced evidence suggesting a close relation between the granitoid folia of the complex gneisses and the foliated granites, it ought to be frankly admitted that there is a striking resemblance between the mineralogical constituents of the granulitic biotite-gneiss and the granitic gneiss.

### III. PORTSKERRY TO ARMADALE.

The crystalline schists into which, in this region, the granitoid rocks have been introduced are of three types:—

1. Granulitic, seen on the coast from Portskerry to Baligal.
2. Wavy biotite-gneiss. On the coast this is concealed by the Old Red Sandstone of Baligal; but it is well exposed on the hills about Beinn Ruadh and Bowside.
3. Granular gneiss of Strathy Point.

The granulitic type is an ordinary fine-grained flaggy schist, composed of quartz, felspar, and biotite, arranged in a mosaic. No traces of clastic structure can be seen, but the rock is very quartzose.

The second type is a highly crystalline gneiss composed of felspar (chiefly oligoclase), quartz, and large wavy flakes of very black mica. It will be described in more detail in the section devoted to the Kinbrace area.

The 'granular' gneiss is an even, medium-grained rock, also composed of striated felspar, quartz, and biotite; but of an exceptional crystalline type, allied to the granulitic, the constituents, however, being on a scale too large for it to be described by that name. Seams of both the other types occur in it, and also peculiar quartzose schists rich in idiomorphic magnetite.

The granitoid rocks are composed of quartz, felspar, and biotite. The felspar is chiefly oligoclase, but those in the eastern part of the area (Portskerry) contain also porphyritic orthoclase.

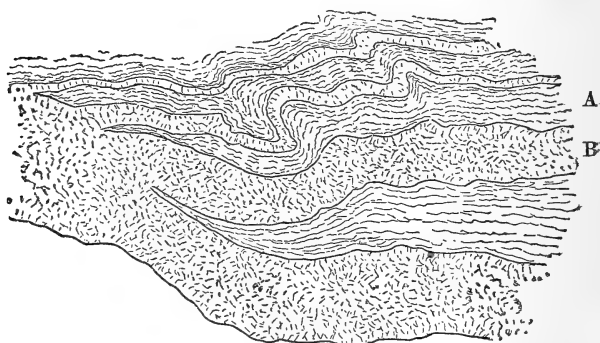
Basic rocks (amphibolites and hornblende-schists) also occur. Their relations are not perfectly clear, but need not be dealt with in this paper.

In all the schists the granites occur as anastomosing lenticular sills. They are exceedingly numerous, even those large enough to

be mapped occupying about one-third of the surface in the well-exposed parts, while the smaller outcrops are innumerable.

The relations to the various types of schists are slightly different. The grauites and the granulitic rocks, however intimately inter-banded, are sharply distinguished from each other. The cliffs of Portskerry display a strongly banded series (fig. 1), composed of rapid

Fig. 1.—*Gneisso-granitic complex, Rudha Ghoiridh, Portskerry.*



A = Gneiss.

B = Granite.

The granite is slightly foliated.

alternations of grey granulitic schist and pink granite, with here and there lenticular sills of foliated porphyritic granite from 2 to 3 yards thick. The thin bands are true veins, for though at first sight conformable with the gneiss, they can be proved to truncate its folia and to anastomose. Of their connexion with the granites there can be no doubt, for the whole series is traversed by precisely similar veins at right angles, which can be seen to be continuous with some of the bands, while cutting others. These veins usually lie along planes of dislocation which fault many of the granite-bands, but these old faults are completely 'healed up,' the crystals interlocking along them, and there being no sign of cataclastic structure.

With regard to foliation :

1. The granite is almost always foliated, the structure being marked out, not only by the orientation of the mica-flakes, but by that of the porphyritic feldspars. Sometimes there are feldspar 'augen,' and even bands, the whole mass being there very complex. But generally the feldspars are angular, and even zonal.
2. The foliation usually follows the cheeks of the sill or vein. Sometimes it is discordant to that of the schist; sometimes it folds rapidly, without the sill folding as a whole; and again here and there, though rarely, a foliation parallel to that of the schist appears to pass through a vein. Finally, in the

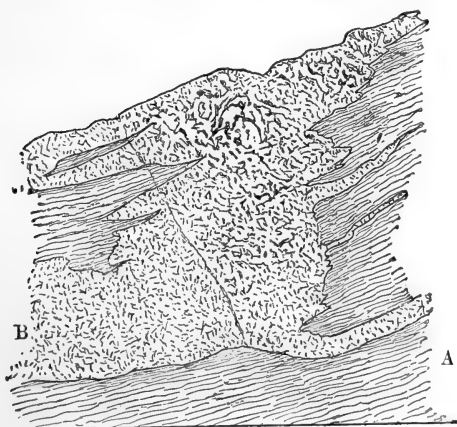
ends of a sill are sometimes seams of biotite whose flakes have the peculiar oblique orientation which they possess in the gneiss.

There are no chilled edges; the margins, indeed, are often fringed with pegmatite; while the thinnest seams are wholly pegmatite.

In the granular gneiss of Strathy Point, the relations of the granite are more intimate. The granites differ slightly in character, as well, porphyritic feldspars not being developed. There is an absence of the parallel interbanding that is so marked at Portskerry, the small sills being lenticular, like the large ones. The sills are extremely irregular in form; they sometimes run right across the gneissic folia for 20 or 30 feet, inosculating, however, along the edges. In and near the basic rocks of Armadale Bay there is an amazing development of highly complex veining, though sills are also common. But most important are the apparent passages between gneiss and granite. Sometimes a sill will have distinct transgressive junctions on one side, while on the other it is difficult to decide where the boundary shall be drawn.

The behaviour of the granular gneiss is singular. Throughout the Point the coarse granitoid rock cuts it; and yet here and there it appears itself to give off veins, and cut granulitic and basic rocks. Indeed, this 'granular' gneiss is the most perplexing of all the types. Very likely it includes rocks of various nature and origin.

Fig. 2.—*Part of base of great sill, Strathy Bay.*



A = Gneiss.

B = Granite.

There is a faint foliation in the granite, rudely parallel to that of the gneiss.

On the cliffs of Glas Eilean and Boursa Cove, magnificent sections, 250 feet high, expose the internal structure of the great sills. They are highly complex synthetic gneisses, consisting of foliated granite,

full of inclusions of all sizes, up to 100 feet long, round and between which the granite passes in gently undulating curves, retaining its own independent foliation, which often truncates that of the inclusions.

In Strathy Bay sills of very massive grey rock, with clear fresh oligoclase and a beautiful waxy lustre, are seen. The junctions are perfectly exposed, showing forms intermediate between sills and dykes (fig. 2, p. 641). Within this mass granites indistinguishable in hand-specimens can be seen to vein each other, both rocks being independently foliated.

Both at Strathy and Portskerry, the whole foliated series is traversed by dykes of pink microgranite. They are unfoliated, and, though compact, have no chilled edges. They cut all the other rocks very sharply.

#### IV. KINBRACE AND KILDONAN AREA.

Although the exposures in this district are far less complete than those on the northern coast, they have especial interest, because the less altered condition of the rocks at Kildonan allows us to see that some, at any rate, of the crystalline schists into which the granites have been introduced must be of sedimentary origin.

The following groups or types can be distinguished:—

1. Quartz-schist.
2. Granulitic biotite-schist.
3. Wavy mica-schist.

All these are truly crystalline schists, composed of interlocking minerals; the structure of Nos. 1 and 2 being that of a granulitic mosaic.

There can, however, be no doubt that No. 1, at any rate, is a highly altered quartz-felspar grit. Not only are clastic grains clearly recognizable in certain parts, but the highly quartzose character, maintained over a large area, makes its sedimentary origin practically certain. There are always some felspar and white mica, and seams of iron ores are a characteristic feature.

Group 2 resembles the granulitic schist of Portskerry, differing only in that a few bands contain muscovite as well as biotite. But its relations to the quartz-schist throw light on its origin. Not only do seams of Group 2 occur constantly within the main mass of Group 1, but the main masses of each always pass one into another through a series of alternations in such a way as to leave little doubt of their common origin. The boundaries on the map are, indeed, quite arbitrary, and it is often difficult to decide how to colour the intermediate types.

Group 3 is different in texture. It is a very wavy foliated schist, composed of both micas, quartz, and felspar (sometimes certainly oligoclase). The micas are much larger than in the granulitic rocks, and the biotite is a deep brown ferruginous variety. Garnet and sillimanite are generally present. The sillimanite is usually in the mica, but sometimes in quartz (*Faserkiesel*). This group passes



into Group 2 in the same way as that does into Group 1. From this, and from the abundance of sillimanite, it seems reasonable to infer that it also is of sedimentary origin. Seams of quartz-schist occur within it.

Granites occur in all these rocks as veins and sills. Those in the quartz-schist are red pegmatitic-looking veins, composed of oligoclase, microcline, quartz, and muscovite; while those in the other schists about Suisgill contain biotite and very little muscovite, their feldspar being (so far as determined) oligoclase, and sometimes probably natron-orthose. All these rocks have sharply-defined margins, and are hardly ever foliated.

Groups 1, 2, 3 follow in order north-westward from Kildonan, till, about Borrobol, a large mass of Group 2 comes in again. When we approach the north-western margin of this, we find that a change has set in. The granites, which hitherto have not been very numerous, now appear in great numbers, and 'injected lit par lit,' as well as along old faults, now completely healed up by interlocking crystallization, just as on the coast of Portskerry, forming with the granulitic schists a 'synthetic gneiss.' A little distance farther on, however, we leave the granulitic type, and enter a tract of coarse, wavy, highly crystalline gneiss, like that of Bowside near the northern coast. It is composed of quartz, feldspar, and very black mica (often olive-green by transmitted light). The feldspars are large and well striated. They are chiefly oligoclase, but albite and orthoclase also occur. Garnet is not uncommon, and sillimanite occurs locally, sometimes most beautifully crystallized.<sup>1</sup>

In spite of the coarsely crystalline texture of this rock, especially the large size of its beautiful striated feldspars, there is a general resemblance in structure to the wavy mica-schists of Suisgill, and in places it could not be distinguished from these; and I am inclined to believe that, although it may contain other material as well which has not yet been separated, nevertheless the greater part of it is the Suisgill mica-schist in a more highly crystalline condition. It occupies a very large area, extending, with only one interruption of  $1\frac{1}{2}$  mile of granulitic gneiss, across the strike, all the way to the Naver.

Now it is in this rock that the most wonderful granitic intrusions occur. The phenomena so clearly seen in the cliffs of Strathy Point are here repeated in their highest intensity. Great sills of granitoid rocks, often a mile in width, range for miles along the country, and every gradation exists between these and the very thinnest bands and seams.

The feldspars of these granites are in all cases so far determined oligoclase, often inclining to andesine, except certain porphyritic crystals of rather rare occurrence, which are natron-orthose. Albite and microcline occur in some small pegmatites. The large porphyritic crystals only are idiomorphic, the rest having the form called by

<sup>1</sup> These and other minerals were determined during field-work from crushed fragments under the microscope; laboratory tests being used afterwards, for confirmation in doubtful cases.

Mr. Barrow 'round-grained,' whether in foliated or unfoliated rocks. The micas are almost always biotite, muscovite being very rare.

Most of the sills are full of inclusions, the smaller sills behaving in every respect like the largest. There are no chilled edges whatsoever.

The junctions are of three kinds:—

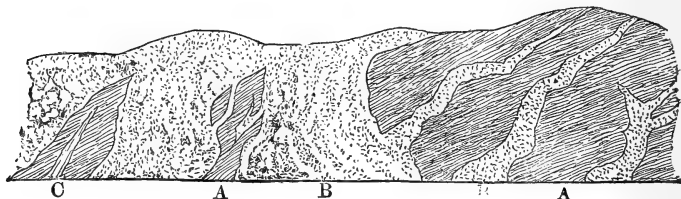
- (a) 'Lit par lit' injection of a kind more subtle still than that where we see parallel beds of schist and granite, for the margins of a sill fade off into the gneiss through a series of thinner and thinner lenticles.
- (b) The ends of a sill fading off into the gneiss by a dovetailing of biotitic folia into the granite.
- (c) True transgressive junctions, where the granite truncates the folia of the biotite-gneiss.

All these three types can be seen in one and the same sill.

Finally, large masses occur in which these relations are carried to such a degree of intimacy as to render it very difficult to decide whether to regard them as granite or as gneiss, difficult even to produce a consistent map, all lines being wholly arbitrary.

The granites are for the most part foliated, the foliation being generally, as on the northern coast, parallel both to that of the gneiss and to the sides of the sill. Cases, however, occur of transgressive junctions where the foliation of the granite follows the cheeks of the sill or dyke, and so truncates that of the gneiss (fig. 3). Foliated granitoid rocks can also be seen to truncate each other, as in Strathy Bay.

Fig. 3.—*Foliated granite and biotite-gneiss, southern bank of Allt Tom na Bradh, Kinbrace.*



[Length of section = about 27 feet.]

A = Biotite-gneiss.

B = Granite.

*Note.*—By an error of the draughtsman, the thin dyke of granite (C) at the left end of the above section has been 'shaded' with lines parallel to the sides of the dyke, instead of lines at right angles to the sides.

The intimate relations here described do not exist in Kildonan. The granites there are not only smaller and fewer in number, but they have well-defined margins. As we pass north-westward they increase, but even in the wavy mica-schists at Suisgill every dyke and sill is sharply separated from the country rock. The inter-

felting and amalgamation come on only in the Kinbrace gneisses. It is clear, therefore, that even allowing that the structure of the wavy mica-schists may have been favourable to these types of injection, the following phenomena are coincident:—

- α. Increase in quantity of granite.
- β. Intimacy of relation.
- γ. Increase of coarseness of crystalline texture in the schists.
- δ. Appearance and perfection of crystallization of sillimanite.

## V. SUMMARY AND CONCLUSIONS.

The foregoing facts suggest important considerations with regard to the nature of intrusion, foliation, and metamorphism.

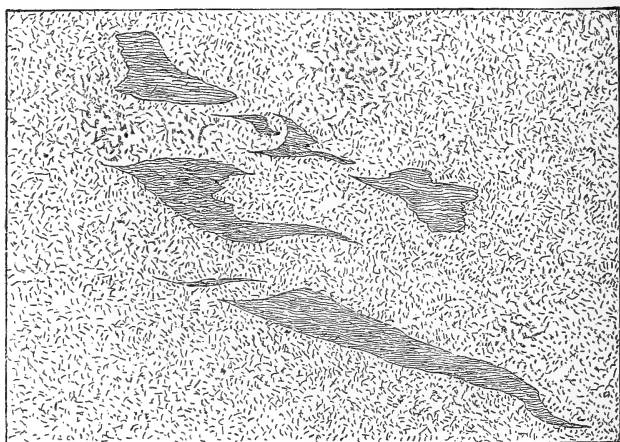
It is certain that sedimentary rocks enter into the crystalline complex, but igneous 'contact' in the ordinary sense cannot be held to be the sole cause of the regional metamorphism. For schists closely resembling some of these (especially Group 2 of Kildonan) cover large areas in which no granite is to be seen (see the description of the schists above the Moine Thrust-plane in *Geol. Surv. Report on N.W. Highlands*, Quart. Journ. Geol. Soc. vol. xliv. 1888, p. 378). The whole series, however, is powerfully folded, and can be shown to have been subjected to shearing stresses, which perhaps points to the initial cause of metamorphism. That the granitic injections were closely associated with the metamorphic processes we have little doubt; but it appears probable that they found the schists already crystalline.

What part 'contact-metamorphism' actually played is not perfectly clear. It is true that as we pass from Kildonan, where granites are small and few, to Kinbrace, where they are numerous and large, we do find what has generally been called a 'progressive metamorphism' in all rocks which could be expected to show it; that the intrusive relations at the same time become more and more intimate; and that sillimanite appears as we pass in, and is most beautifully crystallized in the final stages. From which it seems reasonable to infer that the cause which brought about the introduction of the granite also resulted in these high and peculiar types of crystallization.

Of foliation in the granites there are several conceivable causes. Many of the parallel structures are certainly the remains of biotite-folia belonging to gneisses whose quartzo-felspathic elements have been incorporated with those of the granite, for every gradation can be traced from inclusions retaining their natural orientation (fig. 4, p. 646) down to the merest trains of mica-flakes. Probably much of the foliation is of this nature, at any rate where the gneisses lent themselves readily to it. But neither this nor dynamo-metamorphism can always be appealed to. The numerous cases where the foliation of the granites can be seen to truncate that of the gneiss must be borne in mind. How difficult it would be to distinguish this from the other structure in cases where transgressive junctions cannot be observed, the margins consisting of ranges of lenticles!

The orientation of the porphyritic feldspars in the granites of Portskerry, again, can hardly be other than a truly igneous structure; also the phenomenon of foliated granites cutting each other's foliation.

Fig. 4.—*Inclusions of hornblende-schist in foliated granite, Altiphurst, Strathy Point.*



[Area represented = about 8 square feet.]

Introduction of granite was without doubt the final term in the production of the gneissose complex, but everything points to that process having been long and elaborate. Single sections, even, can be seen showing schists powerfully folded, foliated veins intruded, the whole faulted, and new and complex veins introduced (figs. 5 & 6). It is clear that movement must have continued, or recurred from time to time, from the very first glimpse we get of the metamorphic process till nearly its close, for all veins except the microgranites are cut by faults which are completely 'healed up' by crystallization.

But it is also clear that the whole mass must have remained at a high temperature till the very last, not only from the last quoted fact, but from the absence of any chilled edges whatever, even to these microgranites, which cut every other rock sharply, and are the last members of the whole crystalline series.

If, therefore, the rocks ever passed through a stage of mere mechanical crushing as a result of these movements (and of this the sections observed afford no evidence), such cataclastic structures have been wholly effaced during the later stages of metamorphism.

The evidence of powerful movement which these schists everywhere present certainly suggests that such movement was the initial cause of the whole series of phenomena.

With regard to the granites, it is difficult to believe that they are wholly foreign matter; though here it is necessary to observe the utmost caution, the chemical difficulties being so great.

In all probability, we must wait for satisfactory solutions of these

Fig. 5.—*Veins of granite and pegmatite in hornblende-schist, north-eastern corner of Armadale Bay.*



[Face of cliff = about 4 feet square.]

and other problems in metamorphism until much more is known of the behaviour of the compounds of silicon under high temperature and pressure. The chemical analogies between silicon and carbon are known to be close, but whereas the carbon compounds are

Fig. 6.—*Details of the smaller vein in fig. 5.*



P = Pegmatite.

F G = Foliated granite.

singularly tractable under conditions attainable in experiment, those of silicon are as strikingly intractable. It is not unreasonable to suppose that the silicon atom may have powers of forming groups and compound radicals comparable to those of the carbon atom,

giving rise to similar series of Protean changes<sup>1</sup>; but that these powers are exerted only under conditions which, as yet, preclude experimental investigation. If we consider, however, what amazing results have followed the successful investigation of such a series as  $C_nH_{2n+2}$ , for example, it may well give us pause to reflect on what may happen under conditions which set the silicon atom also free to move.

Let us hope that the door to further knowledge of these matters may not always remain closed, though of its opening there is yet no sign.

Meanwhile the facts described render certain :

1. The existence of relations between granites and crystalline schists so intimate as to amalgamate the two rocks into one gneissose complex.
2. That in such regions the schists become more coarsely crystalline than they are elsewhere.
3. That some of these schists are of sedimentary origin, and that aluminous silicates abound in the most highly crystalline varieties.
4. That the foliated structures in the granites are assignable to at least two modes of origin.
5. That, in spite of powerful earth-movements, there is a general absence of cataclastic structure.

#### DISCUSSION.

Sir ARCHIBALD GEIKIE remarked that it was curious to see how the oscillations of geological theory were reviving the views formerly held, but more recently abandoned, as to the metamorphic origin of some granites. The Authors of the record of careful observations contained in this paper were cautious in drawing deductions, but it was obvious that they were disposed to believe that the granite described by them, though an eruptive rock, had assimilated the surrounding schists and was not separated from them by any sharply-defined differences of composition or structure. Their work ran on lines closely parallel to that of the French Geological Survey under M. Michel-Lévy. They were evidently dealing with the same class of phenomena that had been so closely studied in the Plateau Central of France. A new line of research had in recent years been opened up by the study of the intimate blending of granitic laminae with granulitic and other schists, and though it was still perhaps too early to formulate a definite theory, a marked advance had been made towards a comprehension of the conditions under which granitic intrusions and regional metamorphism are linked together.

Gen. McMAHON congratulated the Authors on their interesting paper, and concurred with them in their main conclusions. He

<sup>1</sup> It is not meant that 'hydrosilicons' play the part of the hydrocarbons, but merely to suggest how much we may have yet to learn regarding silicon.

was interested to see a large specimen on the table illustrating the fine-grained injection of a rock by granite in thin parallel veins, as it closely resembled Prof. Bonney's 'granulitic series' at the Lizard, for which the speaker, in his first paper on that region, had suggested a similar origin. He felt some difficulty in criticizing the paper on one or two points. The Authors suggested that the 'initial' metamorphism of the schists into which the granite had intruded was 'perhaps' due to 'shearing stresses'; but the paper, as read, did not disclose any evidence to prove this contention. The hypothesis might or might not be true, but he was not prepared to accept it without sufficient evidence. The metamorphism might be anterior or posterior to the shearing.

As regards the last point in the paper, the Authors said that the granite was intrusive, but suggested that it was itself a product of the metamorphism of the schists. As the Authors had not attempted to unfold this theory, it would be idle to attempt to criticize it. He would only remark that granite contained highly heated steam, or water, under great pressure, charged with the mineral matter of the granite, and as this solution penetrated into the rocks in contact with the granite, they became impregnated with the minerals of the granite, and might thus appear to blend into granite.

Mr. TEALL said that the Authors had clearly proved that 'lit par lit' injection and other allied phenomena occurred on an extensive scale in the area in question; but they wisely refrained from speaking as if they had solved all the problems connected with the origin of the schists of the district. It was a curious fact that in several areas granitic rocks were found to be intrusive into gneissose rocks which closely resembled them in mineralogical composition.

Speaking on the subject of dynamic metamorphism, he remarked that the rocks into which the granitic magma had been intruded gave abundant evidence of having been folded and sheared—they must at one time have been, so to speak, alive with movement—and he doubted whether a single cubic inch could be found which had not suffered deformation. At the same time the crystalline grains were not fractured, so that crystallization must have taken place during or after the movement. Some critics would apply the theory of dynamic metamorphism only to those rocks which now possessed cataclastic structures; but this limitation had never been contemplated or accepted by those who were mainly responsible for its introduction.

Prof. JOHNSTON-LAVIS remarked that the evidence offered by the Authors as to the high temperature of the matrix-rocks into which the granite was injected probably inferred also a comparatively plastic state, which would favour the extraordinarily complicated ribbon-and-vein structure so characteristic of such regions. High temperature and the approach to fluidity of materials are, as is well known, conditions most favourable to chemical interchange and osmotic diffusion, which are further increased by diversity of chemical composition of the matrix and the injected material and by the affinities between the elements of the one and the other. The

tendency will be, by chemical interchange and osmotic action, to bring the intrusive rocks and those into which they are intruded more and more to resemble each other. Granite in small veins, dykes, and sills can have been formed only in a very hot matrix, in which heat would remain during long periods of time—conditions most favourable to the extensive physico-chemical changes of the intrusive and the intruded rocks. The Authors show how much material of the granite has been derived from the matrix of the intrusions, and we must also consider the loss of components from the granite to the advantage of the matrix. Notwithstanding such evidence as this, and much more of the same nature, a large school of geologists persist in referring all the variations in igneous rocks to internal differentiation and ignore chemical and physical osmosis.

The PRESIDENT also spoke.

Mr. GREENLY, in reply, adduced cases where lenticles of granite occurring in the schists could not be seen to have any communication with any other granite-masses. These supported the view that the granite might not be wholly foreign matter. Referring to remarks by Gen. McMahon and Mr. Teall, he had never yet seen any region of crystalline schists in which there was not abundant evidence of intense earth-movement and deformation. This seemed a fact of the first importance in the study of these rocks. But the time was probably still far distant when it would be possible to generalize concerning them without considerable reserve. He much regretted the absence of Mr. Horne.



38. SEISMIC PHENOMENA *in the* BRITISH EMPIRE. By M. F. DE MONTESSUS DE BALLORE, Officer commanding the Garrison Artillery at Nantes. (Translated by L. L. BELINFANTE, B.Sc., B. ès L. Communicated by Sir ARCHIBALD GEIKIE, F.R.S. Read June 10th, 1896.)

[Abridged.]

[PLATES XXX.-XXXIII.]

## I. INTRODUCTORY.

WITHOUT pretending to have discovered the primary cause of earthquakes, the author is firmly convinced that the plan which he has been elaborating for some years will reduce the present chaos of seismological study to some sort of order, and will enable others to go farther than he has done. This plan is made up of four parts, and the present paper, which deals with the British Empire, is a section of the third part now approaching completion. These four parts, three of which will be briefly outlined in the following pages, are:—

- (1) Formation of an Earthquake Catalogue.
- (2) Refutation of the empirical laws previously enunciated.
- (3) Description of the globe from the seismic point of view.
- (4) Study of seismic phenomena in the United Kingdom and the British Colonies.

## II. FORMATION OF AN EARTHQUAKE CATALOGUE.

More than 100,000 observations of earthquakes have been brought together, 6175 of which have been made use of in the present work.

These observations vary much in value; when they are the result of isolated narratives, gathered from documents of all kinds (but the object of none of which is the special study of earthquakes), we get so-called 'historical series,' generally of little account. If, on the other hand, scientific men have especially busied themselves with these phenomena in any particular country, and have taken careful note of the earthquakes felt by them or reported to them, we get so-called 'seismological series' whose value is the greater the larger the number of years covered by them. Then too some countries are equipped with special observatories containing self-registering seismographs; these furnish so-called 'seismographical series' of very considerable value. It has, however, been shown that these series are not absolutely reliable, because the apparatus being too sensitive and being placed too near great centres of population is apt to register all sorts of vibrations, some of which are due to the passage of heavy railway-trains, or to operations connected with the laying of roads, of gas- and water-mains, etc., and have, of course, nothing to do with true seismic movements.

## III. DESCRIPTION OF THE GLOBE FROM A SEISMIC POINT OF VIEW.

The earthquake-catalogues inform us that in such and such a locality so many shocks have been reported. Now it very often happens that this locality is not the focal centre of the phenomenon. But earth-shocks in general have a smaller 'area of activity' than one might imagine from the narratives of great earthquakes. It has been demonstrated that this area, as a general rule, covers a surface far smaller than that described by a circle of  $12\frac{1}{2}$  miles radius. Consequently the smaller earthquakes, such as are known to have shaken only one locality—and these are by far the most numerous,—are sufficient for showing upon the map the distribution and density of the centres of seismic movement; for, if we do not as a rule know which is the real centre, at least we know a point which is usually much nearer to it than  $12\frac{1}{2}$  miles. By grouping these localities or centres one is enabled to define on the map regions of greater or less stability. It is well, for the sake of giving these rational boundaries, to make use of the chief topographical features of the country—mountains, rivers, seas, etc.

It remains now to find a numerical value for the greater or less stability of a region, what we may in a word term its 'seismicity.' Mallet did by implication trench upon the problem (Fourth Report upon the Facts and Theory of Earthquake-phenomena, Proc. Brit. Assoc. 1858). He drew out a map of the world whereon graduated shading represented the frequency and intensity of earthquakes in various parts of the globe. Unfortunately he had to base his work on estimates, in the absence of actual data. The result was that he often fell into serious error—as, for example, with regard to the Antarctic region, a very stable area. Moreover, that deeply learned seismologist appears to have confounded seismicity with vulcanicity—two entirely different and independent factors, *pace* the usually received opinions.

O'Reilly (Trans. Roy. Irish Acad. 1884) published a seismic chart of Great Britain, and it is a matter for deep regret that the similar chart of Europe (foreshadowed in his highly important alphabetical catalogue of earthquakes in that part of the globe and adjacent regions, *op. cit.* 1886) was never published. These documents, though extremely interesting, are difficult to utilize because they record every shock felt in each locality indicated, without any attempt on the author's part to show whether these localities were centres of vibration or were at all near the centre.

The seismicity of a given area evidently depends upon the number and intensity of the shocks felt within that area. The first factor may be easily tabled, but one cannot say the same of the second. Very fortunately we are enabled to eliminate it for two reasons: the number and intensity of earthquakes are practically proportional in any particular country—by which it is meant that they are severe only where they are frequent, and conversely—provided that we take into account a sufficiently long lapse of time. Moreover, feeble shocks being enormously more frequent than severe shocks, we may neglect the latter in the present investigation.

Thus is one enabled to define the seismicity of a region by the inverse of the square root of an area in which on an average one shock occurs every year. Let us suppose that during a period of  $n$  years  $p$  shocks have been recorded in a region of superficies  $A$ , then its seismicity  $S$  will be expressed by the inverse of  $\sqrt{\frac{pA}{n}}$ . In practice,

we make use of this numerical expression, so that seismicity or instability is the greater the less the number of square miles. The map of the region just dealt with may then be covered with equidistant lines arranged according to the scale thus found. The surface, neglecting a slight error due to irregularity of contours, is then divided into small primary squares wherein one earthquake occurs in each year. As a rule, the scale of maps is not such as to allow of this extremely rational equidistance of divisions.

The data of seismicity thus calculated will be the more exact the greater the number of years over which observations have extended; the data will vary also according to the nature of the observations upon which they are based—whether historical, seismological, or seismographical, as defined above. In order to base any reasoning upon the results it is evidently necessary that the calculated 'seismicities' should all be derived from observations of the same order. Now, any given country can only furnish observations of one order. But the defect, if defect there be, may be made good.

Let us represent the seismicities by the expressions  $S_1, S_2, S_3$ , according as they have been deduced from historical, seismological, or seismographical observations. In 94 cases per cent. the values of the relations of the three 'seismicities' one to the other are known, and one may therefore obtain from these certain empirical formulæ which will serve to calculate any given seismicity by means of the two others. Seismographical observations being few and far between, the seismological seismicities, observed or calculated as above mentioned, have been taken as the standard. We have here the sole means of making rational comparisons.

#### IV. STUDY OF SEISMIC PHENOMENA IN THE UNITED KINGDOM AND THE BRITISH COLONIES.<sup>1</sup>

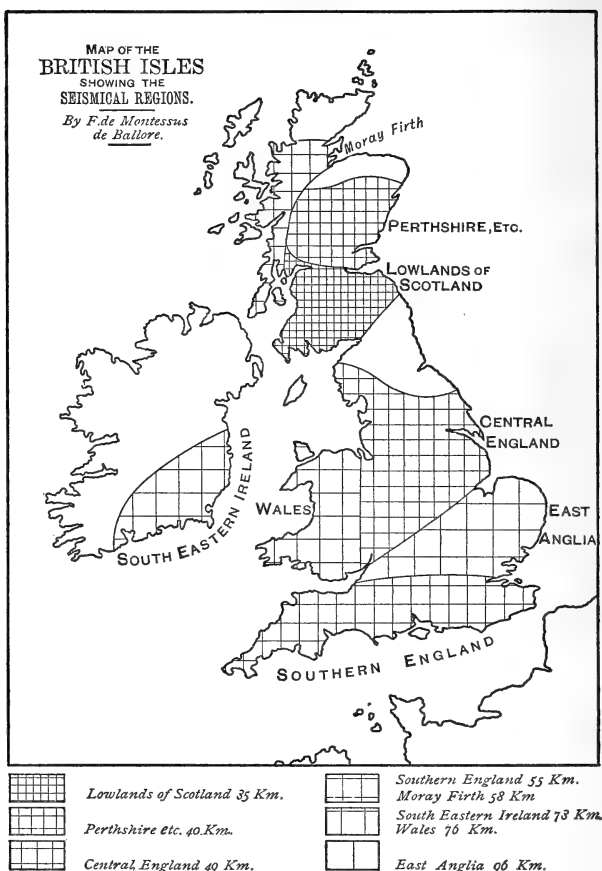
##### § 1. The British Isles. (Pl. XXX. & fig. 1, p. 654.)

Historical records regarding earthquakes are, so far as regards the British Isles, numerous and valuable. On the other hand, the earth's crust here is very stable, and earthquakes in Britain have never caused any serious damage. Seismological documents, and *a fortiori* seismographical documents, are conspicuous by their absence.

The number of shocks recorded is 1023, felt in 221 localities scattered over 10 definite areas.

<sup>1</sup> Calculated seismological seismicities are distinguished in the following pages by an asterisk.

Fig. 1.



### 1. Scottish Lowlands.

$S_1 = 63$  kilom. (1886-1889).  $S_2^* = 31$  kilom.  
(13 localities and 24 shocks.)

This region is limited by the Firth of Clyde, Loch Long up to Ben Voirlich, the valley of Loch Lomond, the Firth of Forth, the German Ocean, and then the Scottish Border from Berwick to Longtown.

### 2. Perthshire and North-eastern Coast of Scotland.

$S_1 = 72$  kilom. (1852-1890).  $S_2^* = 35$  kilom.  
(21 localities and 465 shocks.)

This region is bounded by the preceding one, by the North Sea, then by a line of heights separating the Dee from the Don. The

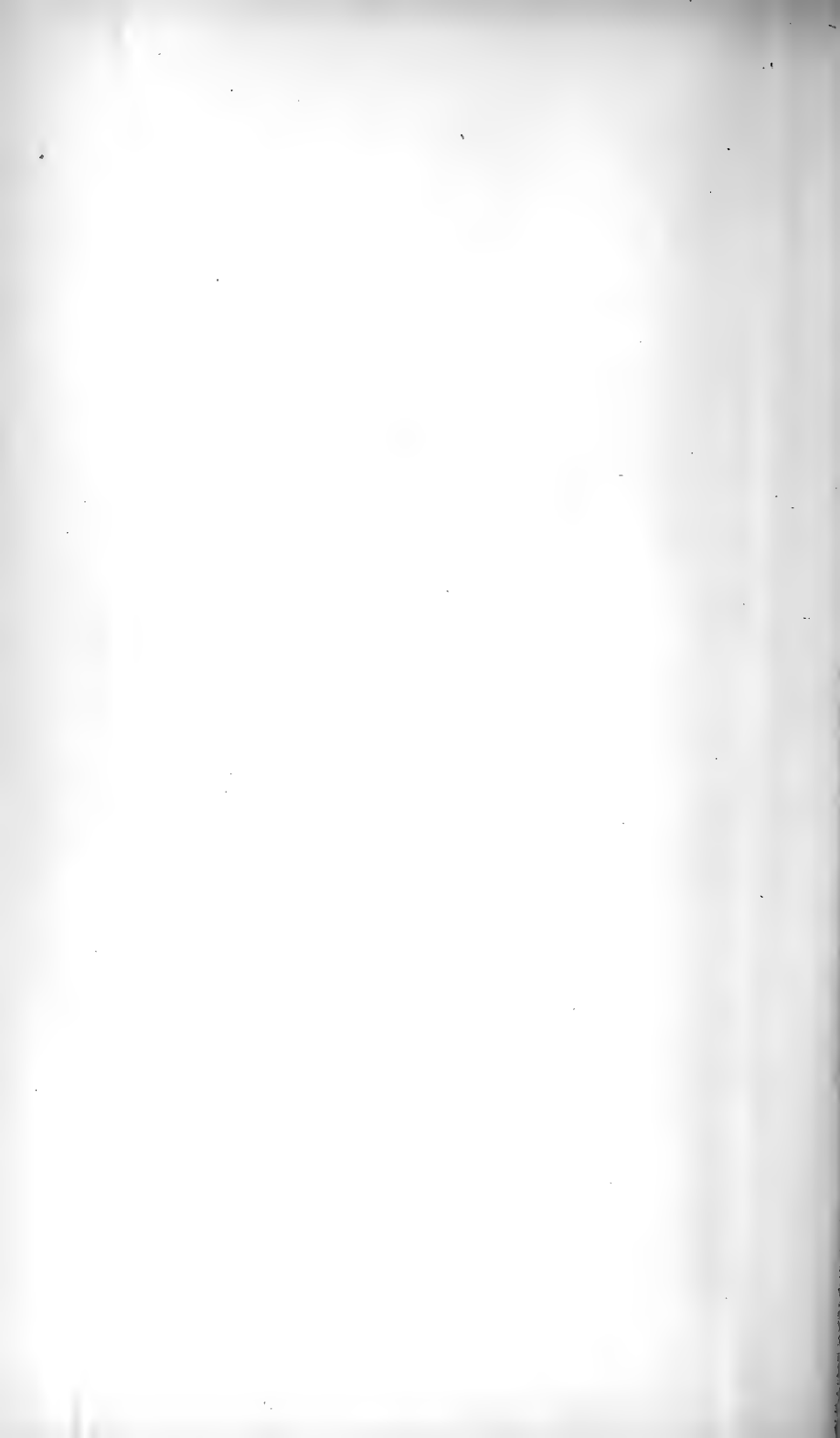




*By F. de Montessus de Ballore.*

The numbers are those of the recorded shocks.







boundary runs along to Ben Voirlich by Cairn Celar and Ben Aber. On several occasions, and more particularly between 1839 and 1852, this region has been visited by several shocks in the valleys of Loch Tay and Loch Earn, and above all at Comrie. The last-named locality is the most unstable spot in the British Isles.

### 3. *Northern and Central England.*

$$S_1 = 89 \text{ kilom. (1833-1873). } S_2 = 44 \text{ kilom.} \\ \text{(65 localities and 159 shocks.)}$$

This region is limited by the two seas, and by three conventional lines running from Irton to Muston, from Chester to Newport (Mon.), from Newham to the Wash. The most unstable portions are situated on the southern slope of the Welsh mountains and in the middle part of the Severn Valley.

### 4. *English Coast of the Channel.*

$$S_1 = 99 \text{ kilom. (1848-1871). } S_2^* = 49 \text{ kilom.} \\ \text{(50 localities and 135 shocks.)}$$

This region is bounded on the north by a conventional line running from Bristol to London. It is particularly unstable in the Cornish and Dartmoor areas. From the seismic point of view the Scilly Isles must be included in it.

### 5. *Caledonian Canal.*

$$S_1 = 105 \text{ kilom. (1852-1871). } S_2^* = 52 \text{ kilom.} \\ \text{(27 localities and 54 shocks.)}$$

This region is bounded by the heights of Monadh Liadh between the Findhorn and the Spey, and by a conventional line drawn from Loch Broom to the Moray Firth through Ben Wyvis. It extends through the Western Isles as far south as Phadda.

### 6. *South-eastern Ireland.*

$$S_1 = 132 \text{ kilom. (1852-1880). } S_2^* = 65 \text{ kilom.} \\ \text{(12 localities and 19 shocks.)}$$

Ireland, very stable as a whole, has only one area subject to earthquakes, and that is the south-east. This is bounded by the sea and by a conventional line drawn from Dublin to Kinsale through Charleville. The portion most often shaken is Cork Harbour.

### 7. *Wales.*

$$S_1 = 138 \text{ kilom. (1839-1894). } S_2^* = 68 \text{ kilom.} \\ \text{(16 localities and 29 shocks.)}$$

This region is bounded on the east by a conventional line drawn from Chester to Newport (Mon.). As it possesses much the same seismicity as South-eastern Ireland, the recorder is tempted to throw the two regions into one—bridging over St. George's Channel.

8. *East Anglia.*

$S_1=174$  kilom. (1848-1871).  $S_2^*=86$  kilom.  
(10 localities and 18 shocks.)

This very stable area is bounded by the North Sea, from the Wash to the estuary of the Thames, and cuts like a wedge into the heart of England up to the Bristol Channel.

9. *North-eastern Scotland.*

This is an extremely stable area, only 11 shocks having been recorded: they occurred in 5 localities.

10. *Shetland Isles.*

In these islands shocks are rarely felt, unless they be those transmitted from Scotland or Norway. Nevertheless, 5 shocks proper to the Shetlands have been recorded.

*England and Scotland.*

Together:  $S_1=185$  kilom.  $S_2^*=91$  kilom.  
England alone:  $S_1=193$  kilom.  $S_2=95$  kilom.

§ 2. *India. (Pl. XXXI.)*

The study of earthquakes has never received due attention in India, notwithstanding the colossal disasters which have wrought havoc in Kashmir and Burma. We possess, however, a good seismological series of records from Assam. Historical documents in India regarding earthquakes are of very small value. Altogether 761 shocks have been recorded from 136 localities spread over 13 regions.

1. *Upper Panjâb and Kashmir.*

$S_1=41$  kilom. (1885-1886).  $S_2=20$  kilom.  
(7 localities and 48 shocks.)

The real boundaries of this area are just as much a matter of dispute as the value of its 'historical seismicity.' Undoubtedly its instability is great—as may be inferred from the catastrophes which have befallen Kashmir and the frequent recurrence of earthquakes in the Upper Panjâb.

2. *Assam. (Fig. 2, p. 657.)*

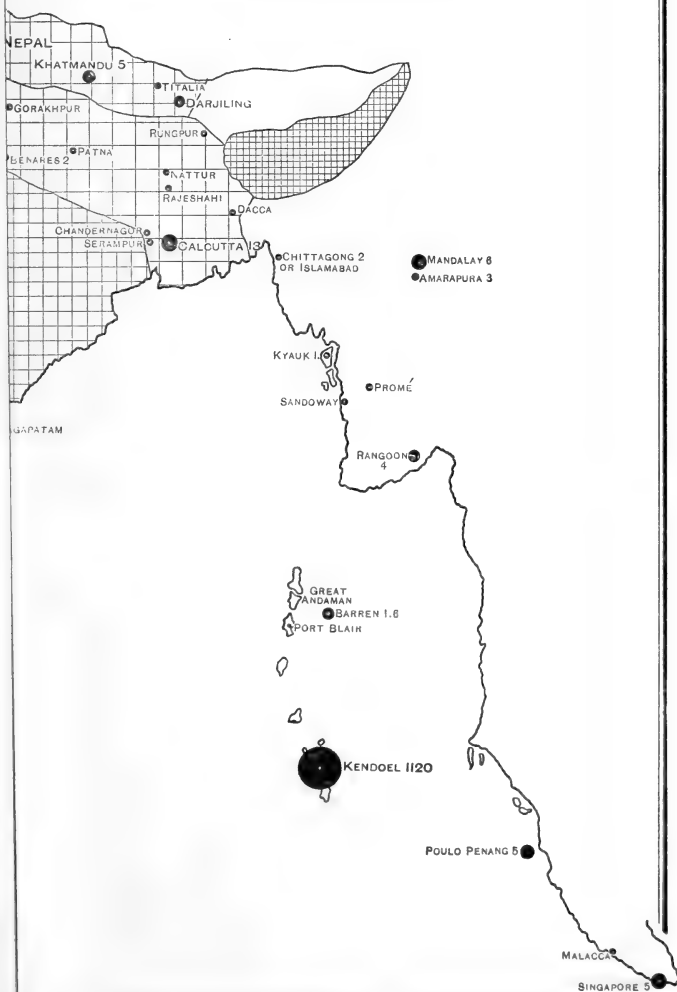
$S_1=114$  kilom. (1839-1849).  $S_2=34$  kilom. (1874-1880).  
(21 localities and 228 shocks.)

This extremely unstable region has been very well studied from the seismic point of view. It is bounded by the Brahmaputra from Karhharbari to Sudyah, and by a conventional line which

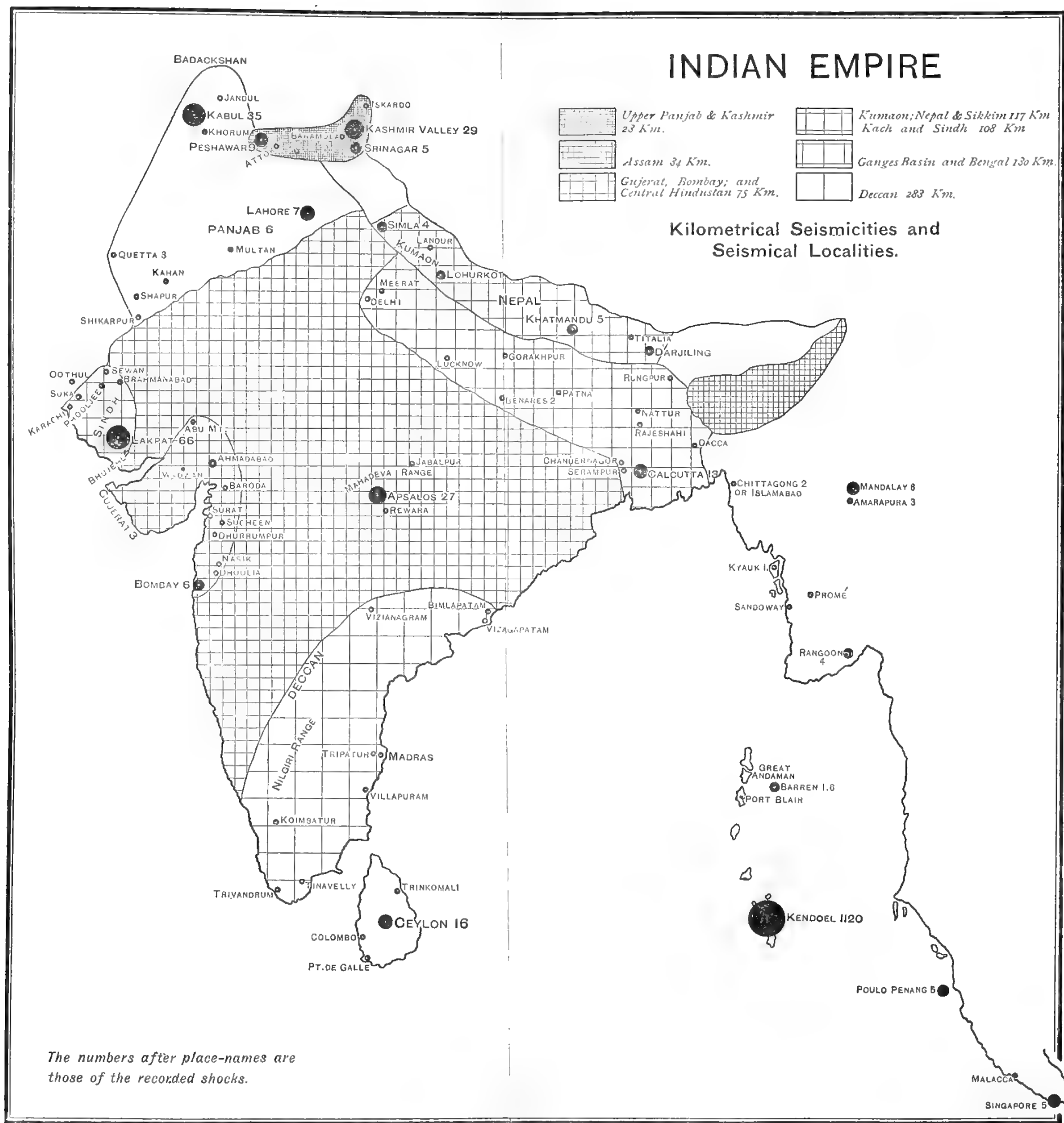
# INDIAN EMPIRE

	Upper Panjab & Kashmir 23 Km.		Kumaon; Nepal & Sikkim 117 Km. Kach and Sindh 108 Km.
	Assam 34 Km.		Ganges Basin and Bengal 130 Km.
	Gujerat, Bombay; and Central Hindustan 75 Km.		Deccan 283 Km.

## Kilometrical Seismicities and Seismical Localities.



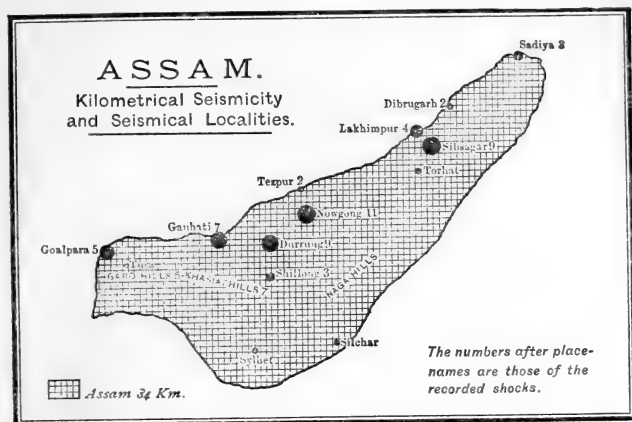






leaves Manipur south of it, but includes within the area the middle and upper valleys of the Barak and its right-bank affluents. Centres of vibration are closely clustered together, and severe shocks have been often felt.

Fig. 2.



### 3. *Gujerat and Bombay.*

$S_1 = 135$  kilom. (1868–1872).  $S_2^* = 66$  kilom.  
(17 localities and 53 shocks.)

The boundaries of this region are very indefinite. There is a rather unstable centre of vibration on the southern flank of the Mahadeva Range.

### 4. *Kách and Sindh.*

$S_1 = 195$  kilom. (1841–1846, 1864–1870).  $S_2^* = 96$  kilom.  
(11 localities and 86 shocks.)

In this region there is a remarkable centre of vibration in the neighbourhood of Lakpat. As to the famous upheaval of the *levée* of Allah or Bhudj, that is a phenomenon which in all probability had nothing seismic about it.

### 5. *Kumáon, Nepal, and Sikkim.*

$S_1 = 212$  kilom. (1828–1833, 1842–1843).  $S_2^* = 104$  kilom.  
(11 localities and 33 shocks.)

This region, which includes the southern slopes of the Himalayas, is probably much more unstable than the above figures would appear to indicate. Darjiling and Sikkim are frequently shaken by earthquakes.

*Southern slope of the Himalayas :*

$S_1 = 71$  kilom.  $S_2^* = 35$  kilom.

6. *Ganges and Bengal.*

$S_1 = 234$  kilom. (1870-1872).  $S_2^* = 115$  kilom.  
(16 localities and 46 shocks.)

This region, comprising the valleys of the Ganges and its left-bank tributaries up to the first slopes of the Himalayas, is in all probability fairly stable. However, Benares has at times suffered some considerable damage.

7. *Deccan.*

$S_1 = 511$  kilom. (1865-1873).  $S_2^* = 251$  kilom.  
(11 localities and 16 shocks.)

This region covers the whole of Southern India, and is very stable.

8. *Panjab and Afghanistan.*

(14 localities and 66 shocks.)

Failing sufficient data, it has been impossible to calculate the seismicity for this region and the following ones. The neighbourhood of Kabul, the valley of Badakhshan, and above all that of Khorum are frequently subjected to earthquakes, which are sometimes rather severe.

9. *Ceylon.*

(7 localities and 10 shocks.)

This island appears to be very stable.

*British Indian Empire:*

$S_1 = 178$  kilom.  $S_2^* = 88$  kilom.

10. *Arrakan and Burma.*

(7 localities and 19 shocks.)

According to Adolf Bastian, shocks of earthquake are frequent in Arrakan, and so very customary in Burma that no notice is taken of them. Anquetil asserts that the surface of Burma is covered with ruins caused by these seismic phenomena, and account is taken of earthquakes in the method of constructing houses and other buildings. Nevertheless, there are few important cities which have not been several times completely destroyed, such as Arrakan, Promé, Paghan-mhyô, Ratnapur, Ava, and Amarapura. Exact data are, however, still to seek.

11. *Malay Peninsula.*

(3 localities and 11 shocks.)

The southern extremity of this peninsula receives pretty frequently the vibration of the shocks from Atcheen.



12. *Islands in the Indian Ocean.*

(5 localities and 125 shocks.)

The Andaman Isles, and especially the Nicobars, seem to possess little stability. The islet of Kendoel in the last-mentioned group has been the site of a great many earthquakes. The Maldives and the Laccadives, on the other hand, appear to be fairly stable.

13. *Indo-China.*

(6 localities and 7 shocks.)

Indo-China is geographically connected with Hindustan, and is therefore quite naturally mentioned here. The absolute silence of all explorers regarding seismic phenomena in this region might lead one to infer that it is extremely stable, at least as a general rule. In Tongking it sometimes happens that vibrations are felt, propagated from the earthquakes taking place in Yunnan.

§ 3. *New Zealand and Australia.* (Figs. 3 & 4.)

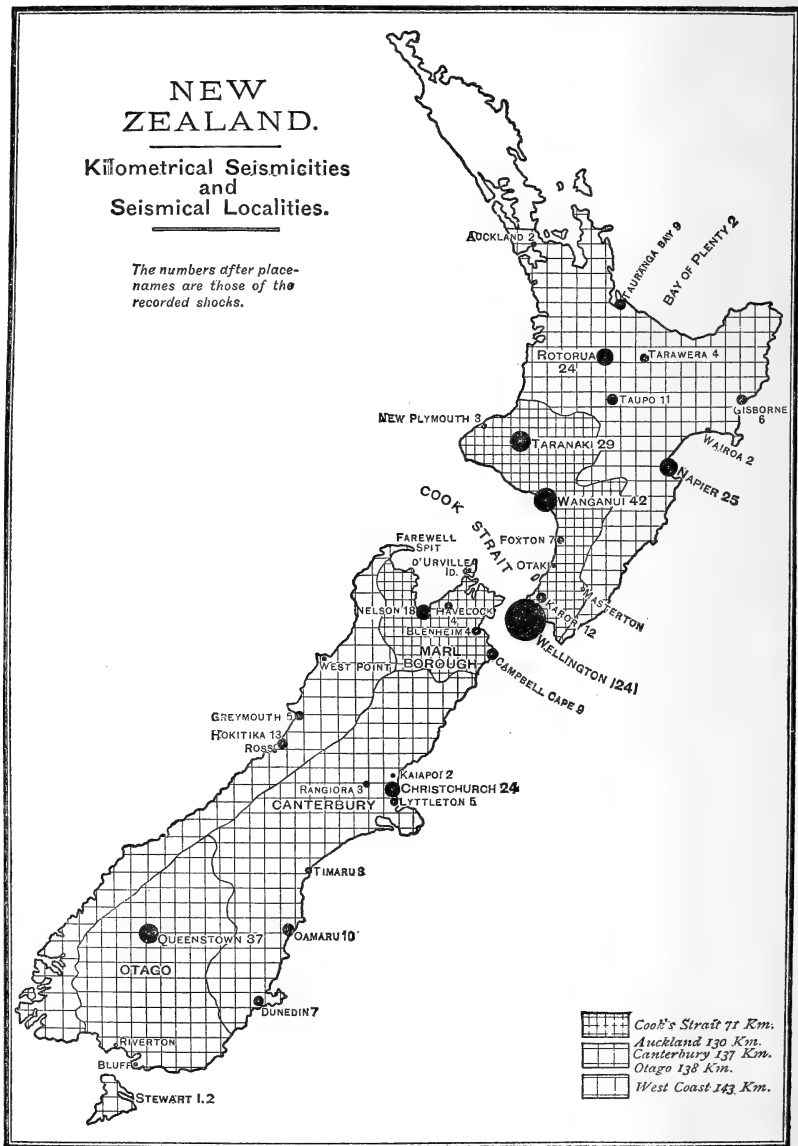
Of Australia, next to nothing is known from the seismic point of view, and very little is known from this standpoint of Tasmania either. But the matter is far otherwise with New Zealand, which makes, with Assam, the only two British colonies where earthquakes have been studied with some degree of care. Earthquakes are frequent in New Zealand, but are rarely very destructive. The two islands have perhaps more to fear from the great tidal waves propagated from far-distant Chile, after having traversed unimpeded the entire breadth of the Southern Pacific. From 25 years back, thanks to the labours of Sir James Hector, we possess a fine seismological series of observations embracing the whole colony, with the exception of two comparatively sparsely-populated districts—the northern end of the North Island beyond Auckland, and the western coast of the Middle Island. There have been recorded 1840 shocks from 81 localities distributed over 7 regions.

1. *Cook Strait.* $S_2=71$  kilom. (1846–1848, 1863, 1868–1888).

(18 localities and 1444 shocks.)

This district bridges over Cook Strait, and its submerged portion is, of course, taken into account in the calculation of the seismicity. It comprises the two watersheds on either shore of the Strait. The dry-land boundaries are, on the north, a line drawn from Mount Whareorino to Cape Palliser, and on the south a line drawn from Cape Farewell to Mount Kaikorara. The town of Wellington was overtaken by a great disaster in November 1848.

Fig. 3.



2. *Auckland.* $S_2 = 130$  kilom. (1869–1888).

(13 localities and 90 shocks.)

This region, comprising the volcanic districts of Tongariro, Lake Taupo, and Rotorua, is bounded on the south by the preceding region, and on the north by the isthmus of Auckland. Its feeble seismicity in comparison with that of Cook Strait is a notable example of the independence of seismic and volcanic phenomena one from the other.

3. *Canterbury.* $S_2 = 137$  kilom. (1868–1888).

(10 localities and 68 shocks.)

This region is bounded on the north by the Cook Strait area, on the west by the longitudinal mountainous ridge which forms the backbone of Middle Island between Mounts Franklin and Stokes, and on the south by the northern slope of the Molyneux river-basin. The considerable upheaval of the coast-line, which has been claimed as an effect of the great earthquake of 1869, can hardly be admitted unless better proofs are forthcoming than those hitherto advanced.

4. *Otago and Stewart Island.* $S_2 = 138$  kilom. (1871–1888).

(5 localities and 47 shocks.)

This region comprises the Molyneux river-basin and Stewart Island. It is bounded by the preceding region and by the range running from Mount Stokes to Tewaewae Bay. As it has much the same seismicity as the preceding region, it might well have formed with it one single area—the eastern slope of the Middle Island.

5. *Western coast of the Middle Island.* $S_2 = 143$  kilom. (1870–1888).

(5 localities and 21 shocks.)

The seismicity of this region is not very well known.

*New Zealand*:  $S_2 = 103$  kilom.6. *Tasmania.* (Fig. 4, p. 662.) $S_1 = 390$  kilom. (1859–1884).  $S_2^* = 192$  kilom.

(6 localities and 10 shocks.)

These values for the seismicity are very uncertain.

7. *Australia.* (Fig. 4, p. 662.)

(24 localities and 71 shocks.)

For want of sufficient data it has been found impossible to calculate the seismicity of this island-continent. There is reason to suspect the existence of an unstable region along Bass's Strait, and that of another in the upper basin of the Murrumbidgee.

Fig. 4.



## § 4. Africa. (Pl. XXXII.)

The vast extent of the British possessions in Africa accounts for the inclusion of a seismic description of this continent (with the exception of the Barbary coast) in the present memoir. Taken as a whole, data are wanting, and only for a few localities do we possess some information—and that more or less vague—as to the intensity and frequency of earthquakes. The groups of islands situated in the Atlantic are not dealt with here.

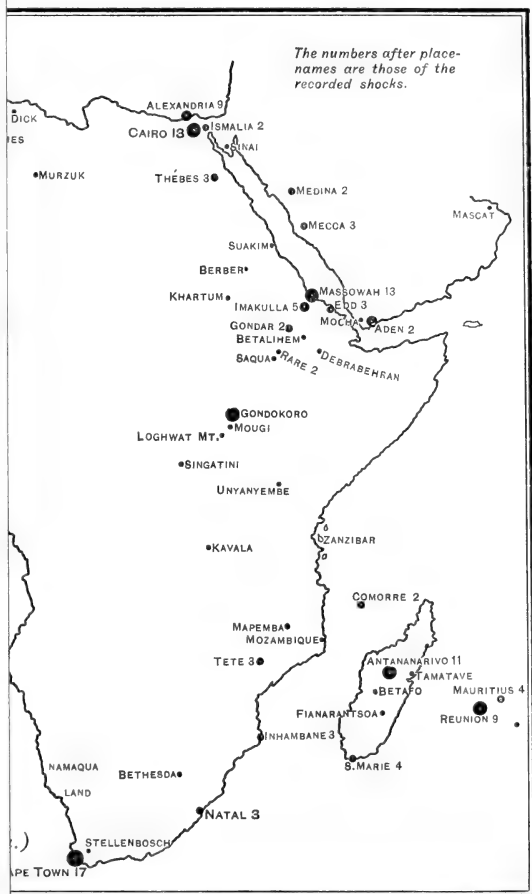
195 shocks have been recorded from 64 localities.

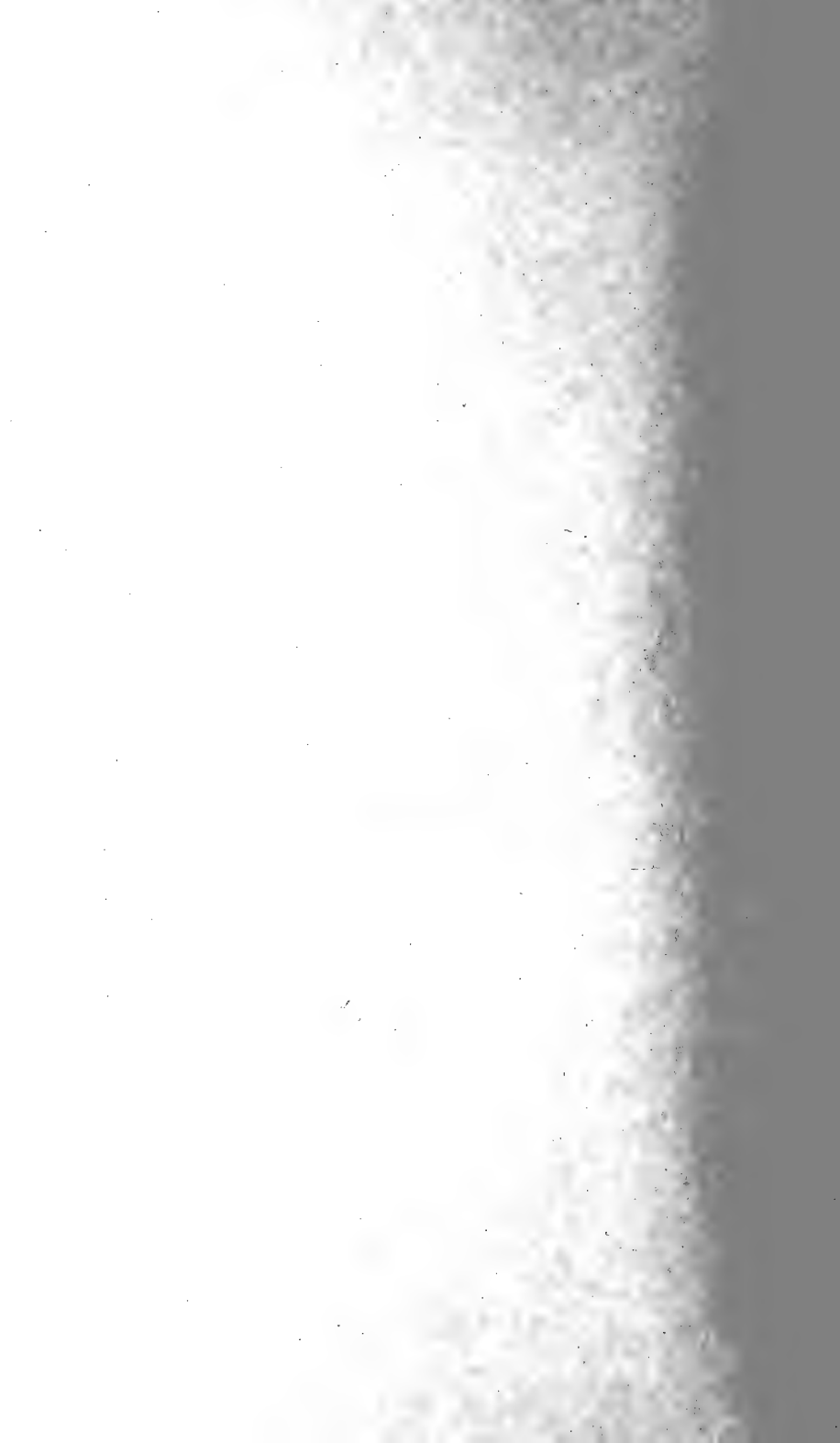
Historians mention a certain number of earthquakes in Egypt, but these are merely vibrations propagated from Syria.

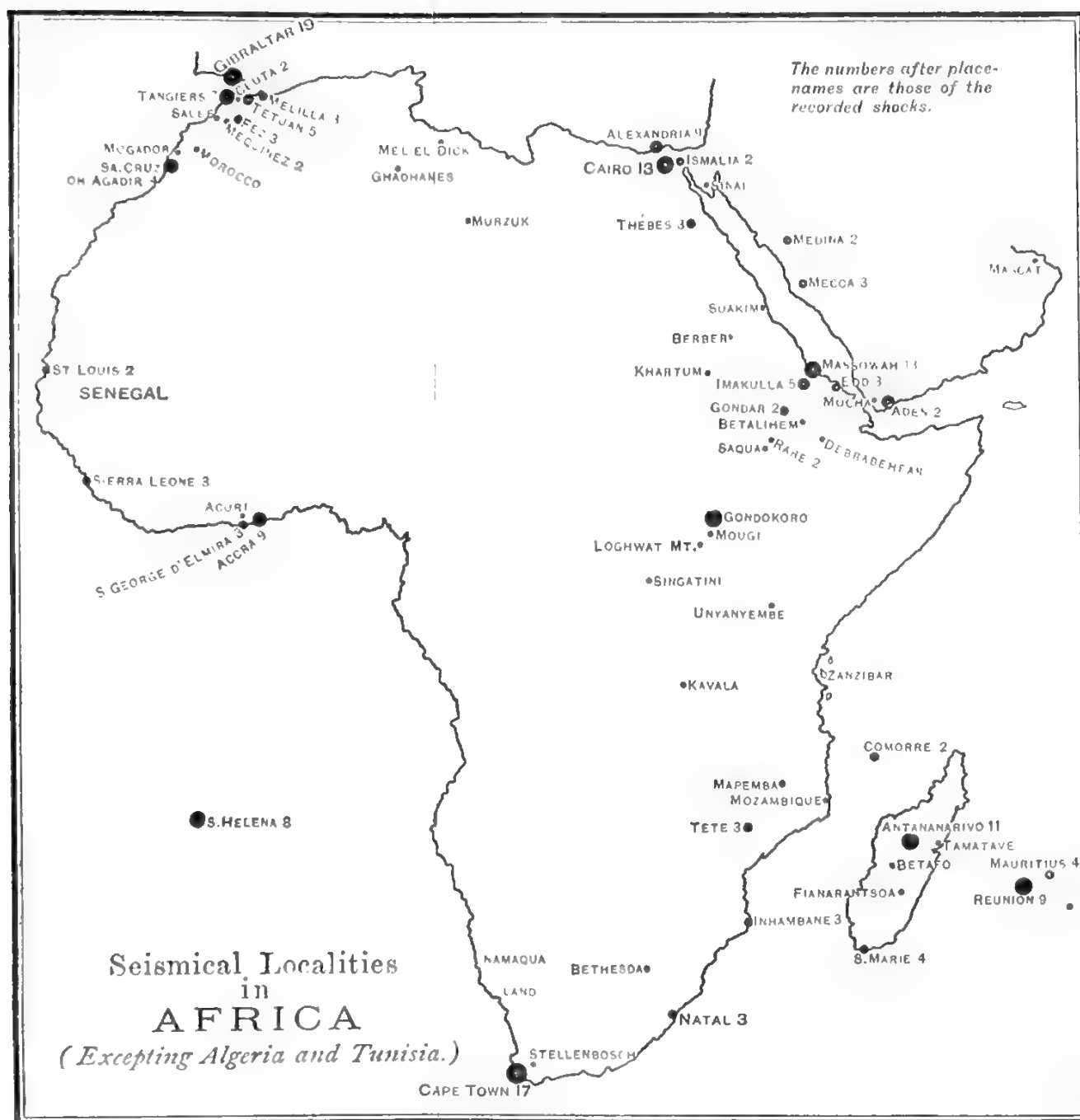
According to d'Abbadie, shocks are of common occurrence at Massowah, and at Imakulla in Sambar. Dr. Blanc, however, records only two shocks at Massowah between February 1st and September 30th, 1864. Kaufmann avers that earthquakes are frequent and severe at Gondokoro, and that they very probably originate from Mount Logwack or Logwat, south of that town. On Th. Kotschy's map this is called the *Erdbebenberg*, or Earthquake Hill, a highly suggestive name. The preceding information is confirmed by the missionary Father Dovyak.

Earthquakes are sufficiently frequent and severe on the Guinea coast between Accra and St. George d'Elmira, but are of rare occurrence on the Senegal coast.

A centre of vibration appears to exist not far from Bu Suada, on the borders of the Sahara.











Morocco is a stable region so far as the interior is concerned, but it is unstable along the Mediterranean coast between Tangier and Ceuta.

Tunisia is stable, save along the coast of the Gulf of Gabes. Utica was the scene of many disastrous earthquakes when under Roman rule.

If we may believe Livingstone, earthquakes are unknown on the Upper Zambesi, at Victoria Falls, or in the hills through which runs the tributary of the Kafue. The same explorer learnt at Tete, on the Zambesi, that in the Maravis country, a short distance from that town, slight shocks are frequently felt.

On the Mozambique coast and at Senna slight shocks are frequent, and all come from the east, which circumstance has caused Perry to ascribe them to the active volcano of Réunion—a view which the distance makes inadmissible, and moreover very few earthquakes occur there.

Lake Tanganyika, on the other hand, and the Upper Congo towards Stanley Falls, may well include some important centre of seismic movement.

Earthquakes are rare at the Cape of Good Hope. A centre of seismic movement possibly exists in Namaqualand, at Rehoboth, where, according to Henderson, subterranean noises and slight shocks are frequently observed.

Despite the activity of the volcanoes of Mauritius, Réunion, and the Comoro Group, earthquakes are of rare occurrence in those islands.

Of Madagascar little is known, in so far as seismic phenomena are concerned, save that the eastern slope is often more shaken than the western.

From St. Helena 8 shocks have been recorded, and 2 from Tristan Dacunya, but none from Ascension.

### § 5. Dominion of Canada. (Fig. 6, p. 664.)

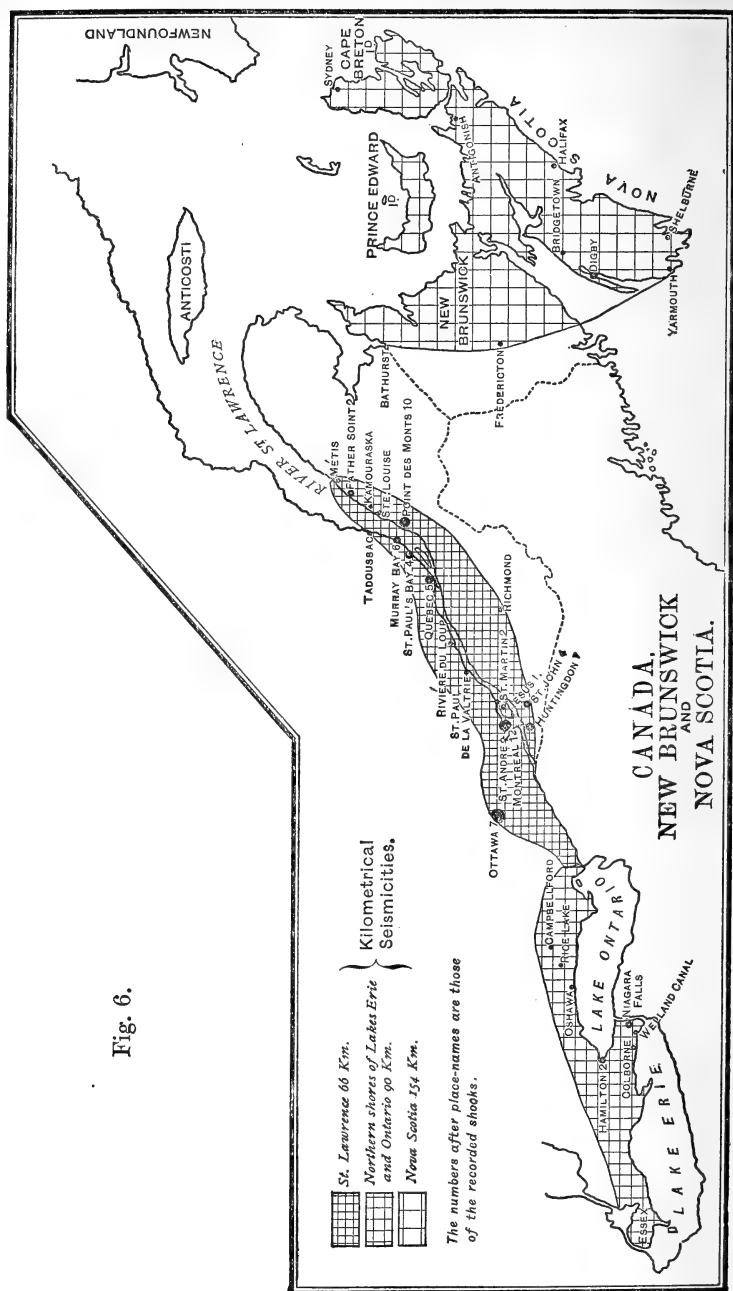
A good series of historical records is available for the St. Lawrence basin, New Brunswick, and Cape Breton Island, colonies where earthquakes frequently occur. Moreover, it is known that Newfoundland and Labrador are very stable. The Quadra Archipelago and Vancouver share in the instability of Washington Territory, and to the two former the seismicity of the last named may be fairly applied ( $S_1=118$  kilom.;  $S_2^*=58$  kilom.).

The Queen Charlotte group appears to be extremely unstable. As to the vast level plains which stretch between Hudson Bay and the Mackenzie River, and the islands of the Arctic Ocean, we are entitled

Fig. 5.



Fig. 6.



to ascribe to them the same stability as that which characterizes the plains of Russia and Siberia.

Records are at hand of 147 shocks in 69 localities distributed over 3 regions.

### 1. *Valley of the St. Lawrence.*

$S_1=120$  kilom. (1879-1888).  $S_2^*=59$  kilom.  
(23 localities and 81 shocks.)

This seismic region merely constitutes a narrow band along both banks of the river, from the point where it issues from Lake Ontario down to Metis.

### 2. *Northern Shores of Lakes Erie and Ontario.*

$S_1=163$  kilom. (1877-1885).  $S_2^*=80$  kilom.  
(14 localities and 16 shocks.)

This seismic region is also very narrow. Quinte Bay and the isthmus between the two lakes appear to be the points of least stability.

### 3. *Nova Scotia, New Brunswick, and Cape Breton.*

$S_1=278$  kilom. (1847-1853, 1884-1886).  $S_2^*=137$  kilom.  
(13 localities and 13 shocks.)

This region is bounded on the west by a conventional line drawn from Nepisiguit Bay, and including the Bay of Fundy.

## § 6. Scattered Possessions.

### 1. *Channel Islands.*

Here 12 shocks have been recorded from 3 localities. The islands are often shaken by vibrations propagated from the neighbouring French coast, and one may apply the seismicity of the latter to them ( $S_1=171$  kilom.;  $S_2^*=84$  kilom.).

### 2. *Gibraltar.*

The peninsula of Gibraltar belongs to a seismic region in Spanish territory, whose seismicity is expressed by  $S_2^*=102$  kilom. Earthquakes are of common occurrence, because of the neighbourhood of the very unstable region of Malaga. From the Gibraltar district 19 shocks have been recorded, and 2 from the Straits.

3. *Maltese Islands.*

(Fig. 7.)

These islands are not very stable, but they are, at all events, more stable than Sicily. From them 65 earthquakes are recorded.

4. *Cyprus.* (Fig. 8.)

The vibrations propagated from earthquakes in Anatolia or Syria have been of frequent occurrence in this island, and on some occasions have caused damage. It is not certain whether many earthquakes originate in Cyprus; only 14 are certainly known to have originated there.

5. *Aden.*

Shocks are not so very uncommon at Aden, and 5 have been recorded there.

6. *Shanghai and Hongkong.*

Shocks are of fairly frequent occurrence in both these localities. They are also shaken by the vibrations propagated from the more considerable earthquakes of Formosa. From Shanghai 12 shocks are recorded, and 5 from Hongkong. From Port Hamilton no records are available.

7. *Virgin Islands.*

$$S_1 = 47 \text{ kilom. (1864-1866). } S_2^* = 23 \text{ kilom.}$$

$$S_1' = 66 \text{ kilom. (1869-1879). } S_2'^* = 32 \text{ kilom.}$$

(5 localities and 656 shocks.)

The Virgin Islands, more especially St. Thomas, are particularly unstable. It is not easy to say which is the most reliable of the pairs of values given above for the seismicity, for the period 1864-1866 is very short, and was perhaps preliminary to the great cataclysm of 1867-1868. In this region, submerged areas are, of course, included, and this must be so in the case of all groups of islands.

Fig. 7.

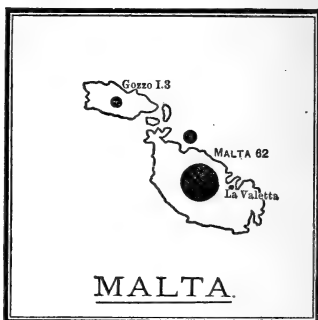
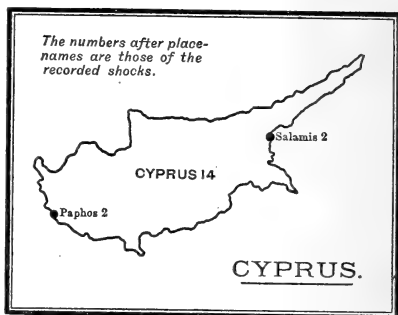


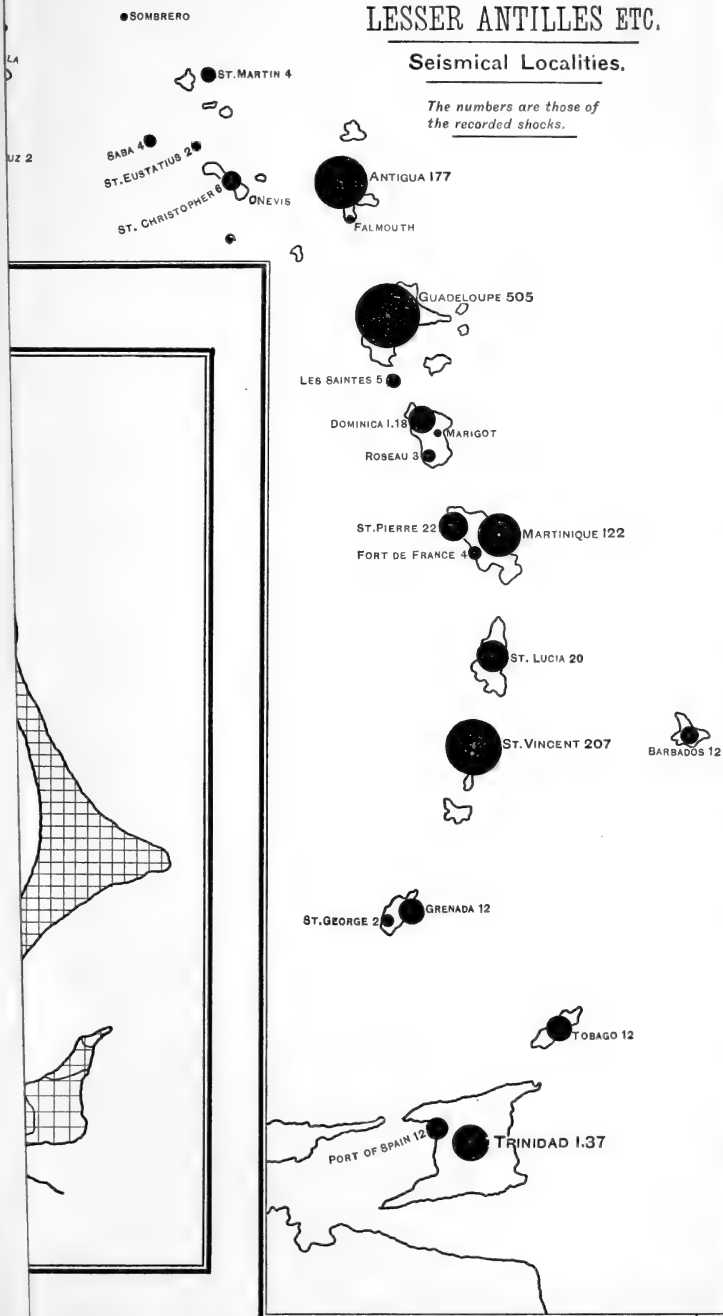
Fig. 8.



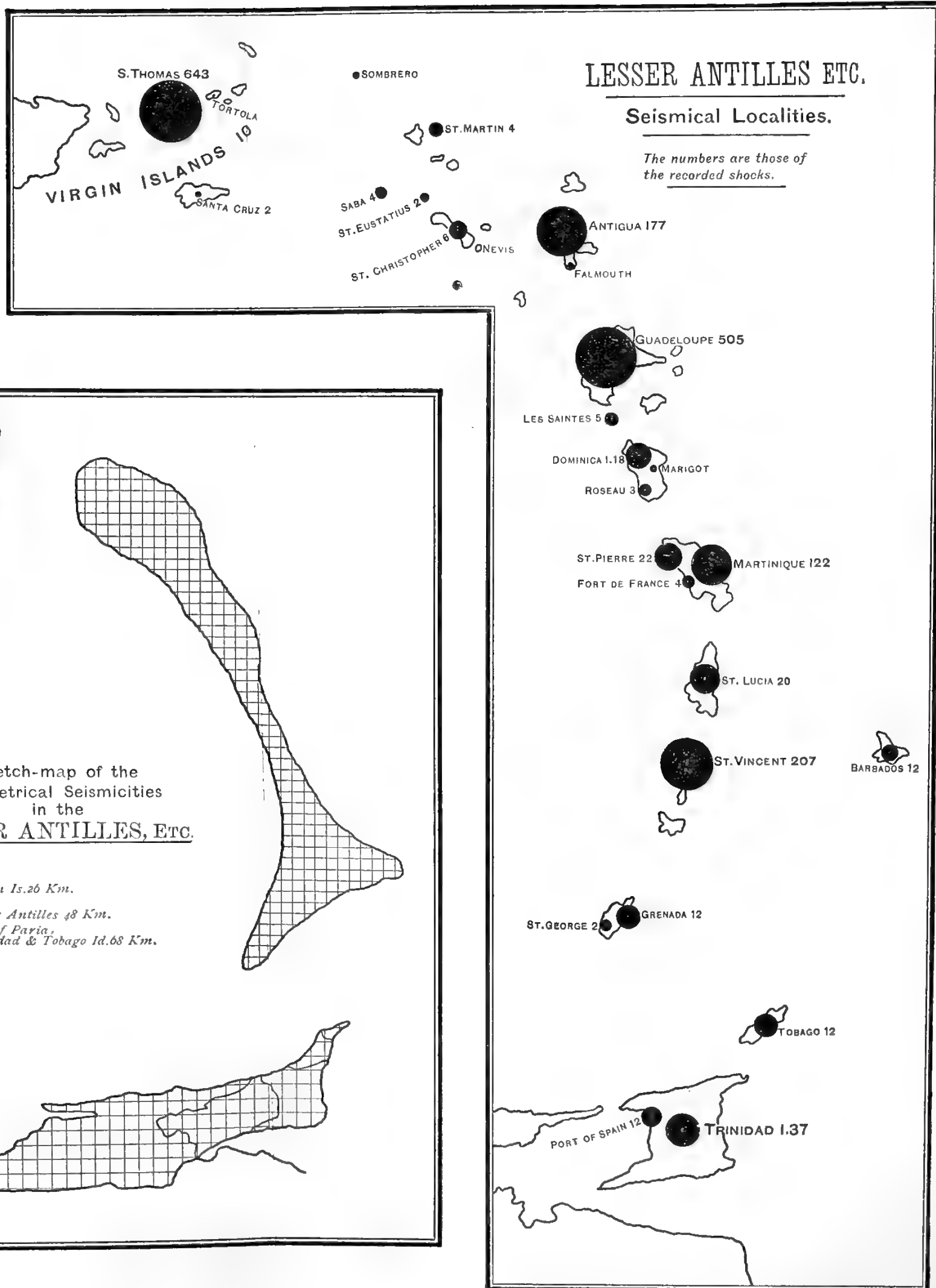
# LESSER ANTILLES ETC.

## Seismical Localities.

*The numbers are those of  
the recorded shocks.*









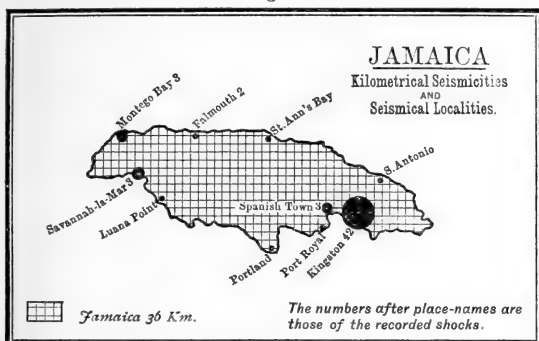


8. *Jamaica*. (Fig. 9.)

$S_1 = 66$  kilom. (1847-1873).  $S_2^* = 32$  kilom.  
(17 localities and 157 shocks.)

This is a very unstable island, and it has been the scene of many a violent earthquake. As most of the shocks recorded were felt at Kingston and Port Royal, it is impossible to say which of the two slopes, northern or southern, is most often shaken.

Fig. 9.

9. *The Lesser Antilles or Windward Islands*. (Pl. XXXIII.)

$S_1 = 86$  kilom. (1845-1871).  $S_2^* = 42$  kilom.  
(37 localities and 1189 shocks.)

This group, wherein the islands belonging to Britain are sufficiently numerous to warrant its inclusion here, is somewhat unstable. Severe shocks have been recorded from it. Nevertheless, its seismicity is lower than the presence of numerous active and extinct volcanoes would lead one to suppose.

10. *Tobago and Trinidad*.

These two islands form part of a seismic region which comprises the north-eastern portion of Venezuela, and they have the same seismicity ( $S_1 = 68$  kilom.,  $S_2^* = 33$  kilom.). 4 localities and 62 shocks.

Fig. 10.

11. *British Honduras*.  
(Fig. 10.)

$S_1^* = 85$  kilom (1846-1856).  
 $S_2^* = 42$  kilom.  
(8 shocks recorded from  
Belize.)

This seismic area is formed by the coast stretching between Belize and Trujillo, along the Gulf of Honduras, but it probably extends into the interior as well.



12. *British Guiana.* (Fig. 11.)

The Guianas are generally stable, and the few shocks felt there come from the Parian Gulf or the West Indies.

2 localities and 3 earthquakes (originating *in loco*) in British Guiana.

Fig. 11.

13. *Other Possessions.*

(Figs. 12 & 13.)

The Falkland Isles are certainly extremely stable. British Borneo and British New Guinea are probably stable too. On the other hand, the converse proposition would appear applicable to the Fiji and the Chatham Groups. Labuan is apparently stable.

Figs. 12 &amp; 13.

In conclusion the author considers it highly desirable that English observers, and meteorologists in particular, disseminated in all these colonies should carefully note all the shocks that occur. The preceding pages have shown how many parts of this vast empire are comparatively unknown from the seismic point of view.

## PLATES XXX.-XXXIII.

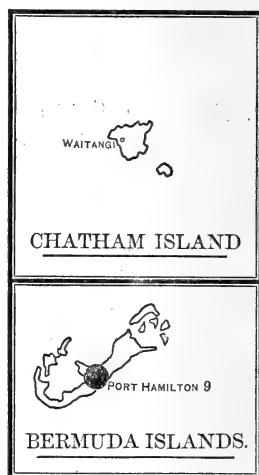
Seismical maps of the British Isles, the Indian Empire, Africa, and the Lesser Antilles.

## DISCUSSION.

Sir ARCHIBALD GEIKIE referred to the published work of the Author in seismology and the laborious nature of the investigations which he had summarized in the present paper. His idea of 'seismicity' was an original one, and, besides being simple and ingenious, seemed to offer a more satisfactory standard of comparison than had previously been available.

The speaker, in communicating this paper to the Society, referred to the recent death of the Foreign Member of the Society, Prof. Daubrée, at whose request he had undertaken to bring M. Montessus de Ballore's investigations before the geological public in this country.

Prof. JOHNSTON-LAVIS also spoke.



39. DUNDRY<sup>1</sup> HILL: *its* UPPER PORTION, *or* the BEDS MARKED as INFERIOR OOLITE (*g* 5) in the MAPS of the GEOLOGICAL SURVEY.  
By S. S. BUCKMAN, Esq., F.G.S., and E. WILSON, Esq., F.G.S.  
(Read May 13th, 1896.)

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## I. INTRODUCTION.

WE must explain our title. It has been difficult to find a designation sufficiently terse and yet duly comprehensive. Had we spoken of 'the Inferior Oolite of Dundry Hill' we should have made use of a term which is notoriously indefinite, has very different values in different parts of the country, and even in its widest application

<sup>1</sup> Dundry probably means 'wooded hill,' 'hill of trees,' *dr-* or *tr-* being the common Aryan base of words for a tree. But other etymologies are possible:—thus the Welsh *din dry* means 'forward hill,' which would be a correct description of the relation of Dundry Hill to the Mendips.

could have been given only to a portion of the strata that we intend to describe. On the other hand, a title such as 'On certain Beds of Dundry Hill' would have been far too vague. The strata which we have investigated form the upper portion—about the upper 100 feet—of that isolated, somewhat flat-topped eminence known as Dundry Hill. They comprise deposits which would usually be known as Marlstone, Upper Lias, Supra-liassic sands, and Inferior Oolite. Owing apparently to a similarity in lithological structure between the Marlstone rock-bed and a bed in the Inferior Oolite itself, the whole of the above-mentioned deposits have been mapped by the officers of the Geological Survey as Inferior Oolite (g 5) around nearly the whole of Dundry Hill.

## II. HISTORICAL RETROSPECT.

Considering that Dundry Hill has always been known as a classical locality for 'Inferior Oolite' fossils, that it is the most westerly deposit of 'Inferior Oolite' north of the Mendips, and that it is within easy reach of a populous city, it must be confessed that its strata have not received any great amount of attention—especially for the purpose of making exact correlation of the deposits with contemporaneous strata elsewhere. Nevertheless, if we were to mention all those papers wherein more or less casual reference has been made to the Dundry rocks, or to the fossils obtained therefrom, it would be easy to make a somewhat lengthy bibliography; but such a compilation would be of little value. We would, however, notice certain publications which have dealt with the strata of this hill, in order to show what our predecessors have accomplished.

Conybeare and Phillips<sup>1</sup> noticed Dundry Hill, and referred to the ironshot nature of the stone; while De la Beche<sup>2</sup> mentioned it, but only in a general way, as a locality for Inferior Oolite. H. E. Strickland<sup>3</sup> correlated the Oolite of Dundry with the Pisolite of Cheltenham, the Cephalopod-bed at Haresfield Hill, and the Oolite of Bridport.

In 1857 Lycett<sup>4</sup> shortly noticed Dundry and compared its beds with those of the Cotteswolds. His remarks are of interest. 'The ragstone' [evidently the Coralline beds] 'seems to belong to the *spinosa* stage; this is underlaid by useful building-freestones and by sandy oolite . . . which probably represent the *Fimbria* stage.' 'The celebrated fossiliferous bed' [evidently the Ironshot Oolite] is presumably correlated with the Cheltenham pisolite; the '*cyncephala* stage' [Cotteswold Sands and Cephalopod-bed] is here represented by only half a yard of sands overlying the Upper Lias Clay.'

<sup>1</sup> 'Geology of England and Wales,' pt. i. (1822) p. 236.

<sup>2</sup> 'Report on the Geology of Cornwall, Devon, and West Somerset,' London, 1839, p. 234.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. vi. (1850) p. 249.

<sup>4</sup> 'The Cotteswold Hills,' London and Stroud, 1857, p. 72.

The correlation of the ragstone and its position above the building-stone are practically all that we agree with in this comparison (see Table VI., facing p. 704).

In 1859 Wright<sup>1</sup> gave an account of the Inferior Oolite, and in his paper published certain 'Notes on Dundry Hill, by R. Etheridge' (*op. cit.* p. 21) This communication is practically a subsidiary paper by the latter author, and the chief matter of interest in it is the sequence of the strata, which was given in the following terms:—

	Feet.
7. Building-stone or Freestone beds .....	12
6. Fine-grained oolite .....	4
5. Ragstones (shells) .....	8
3 & 4. Rubbly Limestones (shells) .....	12
2. Ammonite-bed .....	5
1. Ironshot shelly bed .....	
a. Upper Lias Sands.....	2
b. Lower Lias.....	500

We would notice, in regard to this section, the following points:—

1. That no Middle Lias is mentioned, and on this subject Mr. Etheridge is very emphatic, saying (p. 22), 'In this fine development there are *no traces whatever of the Middle Lias or Marlstone* as exhibited in the Bath district, and in the Cotteswold Range generally.' (The italics are his.)

2. The Upper Lias sands are stated to be 2 feet in thickness; 'they pass downwards into the clays and shales of the Lias beneath.' They are said to underlie a shelly bed which, together with the Ammonite-bed, is 5 feet in thickness. From the list of fossils given it would seem that the 'Ammonite-bed' is what we shall presently call 'the Ironshot Oolite'; but we are quite unaware of any sands within 5 feet of this bed; and in fact we have failed to find any truly sandy strata anywhere in the Dundry range. About the position indicated, and particularly at the western end of the hill—the locality mentioned by the author,—we find sandy limestone and marl, and this is probably the horizon referred to 'Upper Lias Sands' by Mr. Etheridge; but these strata yield *Terebratula Eudesi*, Oppel, and *T. cortonensis*, S. Buckman, indicative of a much later date. (See Table V., p. 699.)

In regard to the other beds we would make the following remarks, taking them in order:—

'No. 1.' From the description given this is evidently the series of beds at the base of what we call 'the Ironshot Oolite'; but it is said to lie 'immediately upon the zone of semi-indurated sands.' In the list of fossils given are *Cirrus Leachi* and *C. nodosus*, which would be found in strata occupying such a position directly above the sands; but they are not to be obtained from the beds immediately below the Ironshot. The explanation is that two beds at different horizons have been confounded—one, the basement-bed at Rackledown, the other, the infra-ironshot bed in the northern road—

<sup>1</sup> 'On the Subdivisions of the Inferior Oolite in the South of England, etc.,' Quart. Journ. Geol. Soc. vol. xvi. (1860) pp. 5-48.

side quarry. The mistake, so far as the latter is concerned, has arisen as the natural consequence of considering the before-mentioned marls with *Terebratula Eudesi* as 'the Upper Lias Sands.'

'No. 2.—The Ammonite-bed.' This, as we said above, is evidently what we call 'the Ironshot Oolite.'

'No. 3.' The ammonites quoted as coming from Nos. 3 and 4 (p. 24) puzzle us entirely, because they are species which we have found beneath and do not find above 'the Ammonite-bed' (Ironshot Oolite).

'No. 5.—The Ragstones of Dundry forming the zone of Ammonites Parkinsoni.' There is evidently some confusion here. The description and the fossils given answer partly to what we call 'the Coralline beds,' and partly to our '*Terebratula Eudesi*-beds.' The locality where the beds are said to occur—to the west of the church—shows only *Terebratula Eudesi*-beds, and no Coralline beds: the locality referred to is obviously Clements' Yard (see p. 679). Further, ammonites are quoted in No. 5; but practically we have found none in 'the Coralline beds,' nor in the strata above 'the Ironshot Oolite.' The beds (No. 5) are placed by Mr. Etheridge below the Freestone and above the Ironshot; but the Coralline beds come above the Freestone, and the *Terebratula Eudesi*-beds are below the Ironshot.

'Nos. 6 & 7.—The Building-stone.' This is said to be the highest set of beds at Dundry; but we find them to be covered by several feet of Coralline Limestone.

We have thus criticized this paper because Wright, in introducing it, said that 'the true relations of its [Dundry Hill] beds of Inferior Oolite with those of other regions have not, until now, been accurately described;' and also because it is actually the only detailed communication on the geology of Dundry Hill which has appeared in the pages of the Quarterly Journal. Unfortunately, by our researches we are unable to confirm the Dundry sequence of strata in the manner presented to us by the author, but we can understand the order given by him on a supposition of some confusion of beds at different levels in various isolated exposures which may not have presented an overlapping series.

In 1875 E. B. Tawney<sup>1</sup> noticed Dundry and Mr. Etheridge's communication thereon, observing that the succession of beds as given by the author cited is open to some doubt, and that 'above these [the Ragstones] Mr. Etheridge places the Building-stones, while others have placed them below the Ragstones.' On his own part Tawney remarks that '*A. Murchisonæ*, *Sowerbyi*, and *Humphriesianus* seem to occur together.'

James Buckman<sup>2</sup> considered that the beds at Dundry and at Bradford [Abbas] were on the same horizon, and that they had not the slightest connexion with the Cephalopod-bed of Gloucestershire, thus correcting some earlier authors.

<sup>1</sup> 'Bristol and its Environs.' Published under sanction of local Executive Committee of Brit. Assoc. 1875.—'Inferior Oolite,' by E. B. Tawney, p. 378.

<sup>2</sup> Quart. Journ. Geol. Soc. vol. xxxiii. (1877) p. 3.

W. W. Stoddart<sup>1</sup> compared Dundry Hill to an island, presumably in the Jurassic sea! He gives a diagrammatic section of the strata of the whole hill in the forefront of his paper; but it is only with the beds referred to in the upper portion of this section that we are concerned. This portion sets forth the construction of Dundry Hill in the following terms:—

		Feet.	Inches.
<i>Parkinsoni</i> . About 23 feet.	1. Freestone .....	16	9
	2. Ragstone .....	6	0
	3. Coral .....	1	0
<i>Humphriesianus</i> . About 20 feet.	4. <i>Echinus</i> .....	1	6
	5. Brachiopoda .....	4	8
	6. Conchifera .....	8	0
	7. Cephalopoda .....	3	0
	8. Ironshot.....	2	0
	9. Midford Sands .....	2	0
	10. Upper Lias .....	4	0
	11. Middle Lias .....	1	0

It will be noticed that Stoddart does give Middle Lias as being present in this section; but in the text the evidence quoted entirely destroys the value of the assertion. 'A bluish marly limestone about a foot in thickness and corresponding to the marlstone . . . so full of the shells of *Am. thouarsensis*, *A. radians*, and *A. aalensis*, that the presence of the Middle Lias is fully justified' (p. 284). There is obviously a mistake here; these are ammonites of what Oppel called the 'Lias-oolith Grenzschichten'—the Cottswold Cephalopod-bed equivalent,—and they have never been found in Middle Lias.

It is easy to see that Stoddart's 7, 8, 9 correspond to Etheridge's 2, 1, *a*; and therefore the remarks which we made concerning the one apply equally to the other. We confess that the section above the No. 7 bed puzzles us. It is true that there are brachiopoda and conchifera in the strata superior to the bed which we suppose No. 7 to denote—namely the hard Ammonitiferous Ironshot,—but certainly not in such numbers as to attract the attention that seems to have been given to them here; whereas there are beds underlying 'the Ironshot' (see Table IV., facing p. 696) to which the description applies very well: they are noticeable for the abundance of fossils of the orders named. We can explain the sequence observed by Stoddart only in the manner which we suggested with regard to Mr. Etheridge's paper, or else on the supposition that Stoddart accidentally reversed a part of his section.

In 1878 Mr. J. F. Walker<sup>2</sup> compared the brachiopoda of Dundry with those of Dorset and the Cheltenham district, pointing out that certain species were common to Dundry and Dorset, and were not found in the Cheltenham district, which has its own peculiar forms. He suggested that a Palæozoic barrier might have separated the Dorset and Cheltenham areas.

<sup>1</sup> 'Geology of the Bristol Coalfield. Part 5. Jurassic Strata.' Proc. Bristol Nat. Soc. n. ser. vol. ii. pt. iii. (1879) p. 279.

<sup>2</sup> '*Terebratula Morieri* in England,' Geol. Mag. 1878, p. 552.

In his interesting survey of the Inferior Oolite rocks Mr. W. H. Hudleston<sup>1</sup> dismisses the Dundry sections in a few words. He says: 'In the present condition of the available exposures it is by no means easy to construct an intelligible section of the Inferior Oolite in this remarkable hill.' The author, however, makes an important observation as to the affinities of the Dundry beds (p. 24). 'Both the facies and lithology of those fossiliferous beds recall some of the most typical of the Dorsetshire sections, in spite of their lying well to the north of the Mendips. But, on the other hand, the large development of coral in the *Parkinsoni*-zone quite distinguishes this remarkable outlier, which topographically must be included within the second [Cotteswold] district, unless we are to regard it as sufficiently important to constitute a region by itself.'

In 1889, one of us (S. S. Buckman),<sup>2</sup> following somewhat on Mr. Walker's suggestion, compared both the brachiopods and the ammonites of Dundry, Dorset, and the Cotteswolds. He came to the conclusion that Dundry was more truly an outlier of the Dorset district than of the Cotteswolds. He theorized as to the manner in which Dundry, during an interval of Jurassic history, might have been cut off from the Cotteswold area. This separation of the areas he supposes might have been brought about by a renewed elevation of Palæozoic rocks during later Liassic time—such elevation being along the lines of the Mendip axis and of the Tortworth barrier; and he considers that the result of such elevations would naturally have been to bring the recently-deposited Jurassic rocks of the affected areas sufficiently above sea-level to form barriers cutting off the Dundry area from communication with the Cotteswolds, and the Cotteswolds from Dorset; but that, as the Dundry strata and their contents are so similar to the Dorset rocks, some direct remains of communication existed between these particular areas; and it was suggested that such communication had been effected around the western end of the Mendip range.

In the early part of 1892 the same writer<sup>3</sup> gave an abridged section of part of the Inferior Oolite of Dundry. He noticed 'the Ironshot,' 'the White Bed below the Ironshot,' and 'the Nodular Bed,' assigning the two former to the *Sauzei*-zone, and the latter to the *concavum*-zone. He further correlated 'the White Bed below the Ironshot' with the *Sauzei*-bed of Osborne (Dorset); but in regard to the exact correlation of 'the Ironshot' itself he was in some uncertainty.

In 1893, as one result of the work done by us for the present paper, S. S. Buckman<sup>4</sup> gave an outline-section of the upper part of

<sup>1</sup> 'Gasteropoda of the Inferior Oolite,' Pal. Soc. vol. xl. p. 56, issued for 1886.

<sup>2</sup> 'The Relations of Dundry with the Dorset-Somerset and Cotteswold Areas during part of the Jurassic Period,' Proc. Cotteswold Nat. F. Club, vol. ix. pt. iv. 1889, p. 374.

<sup>3</sup> 'Inferior Oolite Ammonites,' Pal. Soc. vol. xlv. p. 293, issued for 1891.

<sup>4</sup> 'The Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 508.



Dundry Hill, to correlate its beds with Dorset. He then recognized that strata were deposited at Dundry during the *Sauzei*, *Witchellia*, *discita*, and *concavi* hemeræ, and that 'the Ironshot Oolite,' in a restricted sense, was laid down during the first-named hemera—the latest in point of time. He corrects the supposition that the 'Ironshot' was contemporaneous with the 'Ironshot' of Sherborne; and notes the absence of any strata deposited during the *Humphriesiani* and *niortensis* hemeræ.

In 1894 H. B. Woodward furnished a short account of the Dundry beds in his Survey memoir,<sup>1</sup> but he made only the following divisions:—

Building or Freestone Beds.	}	Zone of <i>Ammonites Parkinsoni</i> .
Ragstones.		
Ironshot Limestones.	}	Zones of <i>Amm. Humphriesianus</i> and <i>Murchisonæ</i> .
Midford Sands.		

No attempt is made to separate the Ironshot limestones, or to distinguish the fossils of the '*Humphriesianus*' and '*Murchisonæ*' zones.

We have given this short summary of the most important notices which have been published concerning the Dundry beds, in order to show what has been accomplished in the interpretation of its deposits. It now remains for us to give an account of our own work.

Our first joint visit to Dundry Hill was made in the autumn of 1887, when our observations showed the desirability of a more detailed account and more accurate correlation of the Dundry strata. Since then we have, together or separately, paid many visits to the hill; we have resided there at different times, and, when we found that the geological structure of certain parts of the hill could not be discovered in any other way, we employed quarrymen to make special excavations. We owe our best thanks to Sir Greville Smyth, Bart., and to J. H. Shorland, Esq., for their courteous permission to make the necessary excavations upon their property; and we are also indebted to their tenants for kind assistance in this matter. Had it not been for these excavations and the information thus obtained, our work would have been very imperfect. Even now it is far from having that completeness which we would desire; and, before such completeness can be obtained, very much more in the way of excavation will have to be done. However, the results which we have obtained are, we hope, of sufficient value to justify the placing of the present communication before the Society.

<sup>1</sup> Mem. Geol. Surv. 'The Lower Oolitic Rocks of England,' in 'The Jurassic Rocks of Britain,' vol. iv. (1894) p. 99.

## III. THE SECTIONS AND THEIR INTERPRETATION.

The sections to be described are taken in the following order: first, from west to east as nearly as may be; secondly, from Dundry church in a direction south-east by south; thirdly, from the church in a south-easterly traverse.

The first section to be noticed is situated towards the north-western corner of the hill in the road-cutting leading from just west of 'The Grove' to Castle Farm. This section shows only a few feet of rocks, mostly belonging to the hemeræ *Sonniniæ-discitæ*<sup>1</sup> capped directly by 'top beds.' Most of the other details are the result of special excavations.<sup>2</sup>

SECTION I.—*Western End, near Castle Farm.*

		ft. ins.	ft. ins.
	1. Thin-bedded, grey, compact limestones, apparently unfossiliferous, extending upwards.		
	2. Pale grey limestone.....	.....	0 4
GARANTIANÆ. <sup>3</sup>	3. Soft, brown, ironshot limestone, with derived nodular lumps of a dense limestone. <i>Astarte Manseli</i> , Buck., common; <i>Ancyloteras</i> , fragment; <i>Montlivaltia</i> ...	.....	0 5
SONNINIÆ.	4. Planed-off top on some blocks. Yellowish-grey limestone, hard and well ironshot. <i>Lima Ethe-ridgii</i> ; <i>Lithodomi</i> at top.....	0 6	
	5. Yellowish-grey ironshot limestone harder than the bed below, with fewer ammonites .....	0 3	
	6. Whitish ironshot limestone, very small iron grains. Ammonitiferous bed. <i>Witchellia</i> , numerous new species; <i>Stephanoteras</i> , various species; 'Stephan.' cf. <i>Sauzei</i> , <i>Sonninia</i> cf. <i>fissilobata</i> at the bottom .....	0 7	
	7. Hard, greyish, sparry ironshot limestone; often has a brown tinge. Perished ammonites of the <i>fissilobata</i> -type .....	0 2	
	8. Brown sandy parting. Large <i>Sonninia</i> cf. <i>ovalis</i> .....	0 1	
			1 7
DISCITÆ.	9. Grey, crystalline, massive limestone; very small and diffused iron grains .....	0 5	

<sup>1</sup> See Table IV., facing p. 696, for the interpretation of these and other terms.

<sup>2</sup> [Since this was written a considerable amount of quarrying has been done here, so that the section is greatly improved. We have been able to add a few details in consequence.—Aug. 31st, 1896.]

<sup>3</sup> The amount deposited during the times of the respective hemeræ is shown by the hemeral names at the left hand, marking the last deposit of the date to which they belong.

SECTION I. (*continued*).

		ft. ins.	ft. ins.
	Brought forward .....	0 5	
DISCITE ( <i>cont.</i> ).	10. Yellow marl parting, irregular <sup>1</sup> ...	0 2	
	11. Grey crystalline limestone in large blocks. <i>Lioceras</i> aff. <i>intermedium</i> , <i>Hyperlioceras</i> , <i>Belemnites Blainvillei</i> , <i>Sonniniæ</i> , spinous and costate species—one aff. <i>S. costata</i> , both in rotten condition. <i>Astarte excavata</i> , <i>Lima Etheridgii</i> .....	0 7	
	12. Laminated grey limestone, with ochreous clay streaks <sup>1</sup> .....	0 2	1 4
	13. Light-grey crystalline limestone. <i>Lioceras intermedium</i> , <i>Hyperlioceras</i> aff. <i>discites</i> , <i>Rhynchonella Forbesi</i> , and belemnites .....	0 5	
CONCAVI.	14. Soft, greyish, earthy limestone with fragments of whorls of a <i>Sonninia</i> of the <i>marginata</i> -type, and imprints of (presumably) <i>Lioceras concavum</i> .....	1 0	
	15. Irregular marl parting .....	0 3	
	16. Light-grey sandy limestone in two blocks, with brown earthy marl. <i>Terebratula Eudesi</i> , <i>T. cortonensis</i> , and <i>T. perovalis</i> .....	1 2	
	17. Clay parting .....	0 1	
	18. Light grey, nodular, sandy limestone and clay infillings between the blocks .....	0 7	3 6
BRADFORDENSIS & MURCHISONÆ.	19. Light-grey nodular limestone and clay infillings. <i>Zeilleria anglica</i> (Oppel) in the limestone .....	1 0	
	20. Do. more sandy; no fossils seen ...	3 0	
	21. Light grey earthy limestone. <i>Terebratula Eudesi</i> , <i>Trigonia striata</i> , <i>Lioceras</i> cf. <i>bradfordense</i> .....	0 6	
	22. Clay parting. <i>Z. anglica</i> .....	0 1	
	23. Grey, earthy limestone, somewhat coarsely ironshot .....	1 9	6 4
OPALINI.	24. Do. more coarsely ironshot. Large <i>Lima</i> aff. <i>Etheridgii</i> . Scattered black phosphatic concretions in the lower 6 inches .....		1 6
AALENSIS.	25. Blue, compact, argillaceous limestone. <i>Grammoceras subcompactum</i> ; numerous lamellibranchs and gasteropods indeterminate; casts of <i>Cucullæa</i> sp., <i>Inoceramus</i> , <i>Amberleya</i> sp. ....	0 3	
DUMORTIERIÆ.	26. Greenish-blue clay, measured by the level and reckoned to be in all .....	50 0	
	Excavation made lower down the hill by the roadside :—		
DISPANSI.	27. Pinkish to grey, dense, earthy limestone—a few large iron specks. <i>Grammoceras fallaciosum</i> .....	0 4	

<sup>1</sup> These clay streaks are impersistent, and occur at various levels.

SECTION I. (*continued*).

		ft. ins.	ft. ins.
STRIATULI.	28. Greenish-grey, earthy limestone, coarsely ironshot. <i>G. striatum</i> . Pecten, belemnites .....	.....	0 2
BIFRONTIS.	29. Blue, argillaceous limestone, irregularly speckled with large iron grains. <i>Hildoceras bifrons</i> , belemnites. <i>Rhynchonella</i> sp. ...	.....	0 2
FALCIFERI.	30. Pinkish argillaceous limestone, very few iron grains. <i>Harporoceras falciferum</i> , <i>Dactylioceras commune</i> .....	.....	0 2
CHARMOUTHIAN AGE.	31. Greenish-blue clay visible .....	.....	7 0

Beginning at the base, the first point to notice is the absence of the marlstone—a fact also further confirmed for the western part of the hill by excavations at Elwell Spring giving the same result. As will be seen in later sections, the marlstone is found in places interposed between beds 30, 31.

Next, the thin deposits (Nos. 27–30), yielding the same species of ammonites as the base of the ‘Cephalopod-bed’ of the Cotteswold range *plus* ‘Upper Lias,’ are important; and then the thick mass of clay (No. 26) proved at the other end of the hill to have been deposited during the *Dumortieræ* hemera, contemporaneously with the middle part of the Cotteswold Cephalopod-bed. All these deposits show a thickness of about 50 feet, which would have been formerly called ‘Midford Sands and Upper Lias’—a marked difference from the results given by Etheridge and Stoddart (see pp. 671, 673).



The evidence concerning the deposits made during the *bradfordensis* and *Murchisonæ* hemeræ is not very satisfactory here; and it could hardly be so without excavations made on a much more costly scale than we were able to undertake. *Zeilleria anglica*,<sup>1</sup> however (see Nos. 19 & 22), marks a very definite horizon in Dorset<sup>2</sup>; it lived more or less contemporaneously with *Ludwigia Murchisonæ*, and perhaps died out just before *Lioceras bradfordense*; but on this point further evidence would be desirable.

Above the horizon of *Zeilleria anglica*, the next noticeable datum-line is that of Bed 8 with *Sonninia* aff. *ovalis*, Quenstedt. Between these two horizons are certain beds with species of *Hyperlioceras* in the upper part and species of the *concavum*-type lower down.<sup>3</sup>

Lastly, it is to be noted that the planed-off top, indicating denudation, appears on a bed which we assign by its ammonites to the deposit that we shall hereafter call the Lower White Ironshot, consequently there is a distinct non-sequence between Beds 4 and 3, which is partly filled by some strata met with in sections to be described presently.

<sup>1</sup> See note, p. 702.

<sup>2</sup> See ‘The Bajocian of the Sherborne District,’ Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 489.

<sup>3</sup> The peripheral areas of *Hyperlioceras* and of the *concavum*-type of ammonite leave distinct impressions, the former bitabulate , the latter fastigate .

The next section to be noticed is that at Clements' Yard, near the church. Bed 3 in this section is the equivalent of Beds 4-8 of the Western-end Section; and it is also capped directly by strata of the *Garantianæ* hemera.

SECTION II.—*Clements' Yard, on the right-hand side of the road from the Church to 'The Grove.'*

		ft. ins.	ft. ins.
GARANTIANÆ.	1. Light-grey stone with <i>Acanthothyris spinosa</i> ..... exposed about	0 10	
	2. Rubbly marly limestone, slightly ironshot. <i>Astarte Manseli</i> .....	0 2	
SONNINIE.	3. Whitish ironshot limestone. <i>Witchellia</i> numerous; <i>Sonninia</i> , <i>S. cf. fissilobata</i> at the bottom ...	1 6	1 0
	4. Pinkish limestone. <i>Sonninia</i> of the <i>ovalis</i> type; abdomen showing ...	0 6	
	5. Irregular ochrecus marly parting...	0 1	
			2 1
DISCITE.	6. Light-grey, slightly ironshot limestone, with earthy and ochreous partings (horizontal and vertical). <i>Terebratula Eudesi</i> , <i>T. cortonensis</i> , <i>T. perovalis</i> , belemnites .....		1 10

The beds above the topmost deposit at Clements' Yard are found in the Freestone Quarry, near the Church, of which the following is the section:—

SECTION III.—*The Freestone Quarry near the Church.*  
(*Mr. Towle's Quarry.*)

		ft. ins.	ft. ins.
CORALLINE BEDS.	1. White limestone in one thick bed—a crystalline rock of open texture, conspicuous from beds below on account of its greater resistance. Corals, echinid spines, polyzoa. This bed caps the quarry in certain places ...	1 6	
	2. Thin-bedded, whitish ragstones with grey streaks along centres, in beds 2 or 3 inches thick or a little more, mixed with marl. <i>Zeilleria Waltoni</i> , <i>Terebratula globata</i> , corals .....	6 0	7 6
THE FREESTONE BEDS.	3. Pale-grey, white, or yellow limestone, about 9 inches thick, passing downward without any hard-and-fast line into massive, compact, light-yellow ragstone.	5 9	
	4. Compact pale freestone, the most valuable bed of Dundry stone, somewhat variable in thickness .....	12 0	
SONNINIE.	5. Light stone with <i>Witchellia</i> exposed in a fissure of the quarry. (Now filled up—1895.)		17 9

Bed 5 of this section is the same as that numbered 3 in the Clements' Yard exposure. Between it and the Freestone there is very probably some representative of Beds 1 & 2 of Clements' Yard; the inaccessibility of the fissure prevented accurate determination in this matter. But the point to be noticed is that the beds of the *Sonninia* hemera are not capped by any representative of the Ironshot Oolite, either here or at Clements' Yard.

The thick freestone-beds Nos. 3 & 4, especially the latter, yield a stone of considerable economic importance; they are capped by a few feet of coralliferous stone and marl which we have termed the 'Coralline Beds.' Several species of corals have been obtained from these deposits, as well as many specimens of *Zeilleria Waltoni*, and, less plentifully, *Aulacothyris carinata*, *Rhynchonella plicatella*, *Rh. subtetraedra*; and from the same bed elsewhere *Acanthothyris panacanthina* rarely. These brachiopods seem to indicate that the Coralline Beds were contemporaneous with the 'top beds' of Broad Windsor, yielding '*Stephanoceras zigzag*.' If that be so, the Dundry freestone would be equivalent to the 'FOSSIL BED' of Halfway House, Dorset, which yields *Strigoceras Truelli* and *Parkinsonia dorsetensis*, in which case the date of the deposition of the Freestone would be *Truelli* hemera.<sup>1</sup>

The next section is one of the best known at Dundry; it is on the eastern side of the main road, on the northern flank of the hill, not far from the 'Butchers' Arms.'

SECTION IV.—*The Northern Main-road Quarry, near the 'Butchers' Arms.'*

		ft. ins.	ft. ins.
CORALLINE BEDS.	1. Rubble and soil .....	about	3 0
	2. Grey, crystalline, lenticularly-bedded, coralline limestone. Many corals .....	2 6	
	3. Greenish clay with dark crystalline limestone. <i>Zeilleria Waltoni</i> , <i>Terebratula</i> sp. nov., <i>Acanthothyris panacanthina</i> , and a number of micro-brachiopoda .....	2 0	
			4 6
EQUIVALENT OF DUNDY FREESTONE.	4. Whitish, regularly and thinly-bedded, compact limestones with small iron specks. (The top bed bored.) .....		4 0
SAUZEI.	5. Yellowish-brown ironshot limestone—the well-known fossiliferous horizon. ' <i>Stephanoceras Sauzei</i> , <i>Sonninia Sowerbyi</i> , <i>S. corrugata</i> ; many 'mamillate' <i>Sonninia</i> ; <i>Stephanocerata</i> of the <i>Bayleanum</i> -type; <i>Acanthothyris paucispina</i> ; <i>Terebratula</i> sp.; numerous lamellibranchs, such as		

<sup>1</sup> See 'The Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 487.

## SECTION IV. (continued).

		ft. ins.	ft. ins.
SAUZEI (cont.).	<i>Astarte multicostata</i> , <i>Ctenostreon pectiniforme</i> , <i>Ostrea explanata</i> , <i>Myacites jurassi</i> , <i>Cucullæa oblonga</i> ; and many gasteropoda, e. g. <i>Pleurotomaria elongata</i> , <i>Pl. ornata</i> , <i>Pl. granulata</i> , <i>Pl. sulcata</i> , <i>Pl. paucistriata</i> , <i>Trochus Zetes</i> , <i>Ataphrus lævigatus</i> , & <i>Cerithium subscalariforme</i> . (The top flat and planed off.) .....		1 0
WITCHELLIE.	6. Whitish, argillaceous, ironshot limestone; when wet, soft and much broken up; the upper 2 or 3 inches more compact and generally adherent to the base of the Ironshot. Many lamellibranchs and ammonites; the horizon for numerous <i>Witchellie</i> , especially involute, costate forms; <i>Myoconcha crassa</i> , <i>Opis similis</i> , <i>Astarte excavata</i> , <i>A. elegans</i> , <i>Pleurotomaria oxytera</i> , <i>Pl. armata</i> ..... 0 5	0 5	
	7. Brown marl ..... 0 2	0 2	
	8. Brownish-grey ironshot limestone. Belemnites, bivalves, and univalves ..... 0 7	0 7	
			1 2
SONNINIE.	9. Grey ironshot limestone, with many <i>Sonninie</i> and <i>Witchellie</i> ..... 0 8	0 8	
	10. Brownish-yellow shelly limestone, very much speckled with small iron grains; at the top of this comes often a bed of brownish sand about 3 inches thick, with numerous more or less perished <i>Sonninie</i> of the <i>ovalis</i> -type, marking a conspicuous horizon in the quarry ..... 0 9	0 9	
			1 5
DISCITE.	11. Yellowish-brown limestone with compact ochreous marl. Umbilicate <i>Hyperlioceras</i> , <i>Terebratula Eudesi</i> , and <i>T. cortonensis</i> ..... 1 0	1 0	
	12. Yellowish-brown limestone with small ochreous specks. <i>Terebratula Eudesi</i> ..... 0 5	0 5	
	13. Light-coloured limestone, pale grey below, yellow-ochreous and marly above ..... 1 0	1 0	
			2 5
	14. Light-grey limestone with small ochreous specks. (Below present floor of quarry—1895.)		

The correlation of this section with those previously given may be commenced at the horizon of *Sonninia fissilobata-ovalis* (bed 10), which is well marked. Below that horizon the rocks are seldom exposed, but we are able to record the beds (Nos. 11-14) with

*Hyperlioceras* and *Terebratula Eudesi*, similar to beds of the same date at the Western-end Section (p. 676).

The most noticeable features in this section are beds Nos. 6–8, yielding a fine series of *Witchelliae*, and the overlying Ironshot Oolite, yielding *Sonninieæ* of the *propinquans*-type, with '*Stephanoceras*' *Sauzei*. These beds are wanting from the sections previously described; but in this part of the hill they have escaped 'The Bajocian denudation.'<sup>1</sup> Still, there is a non-sequence between Beds 5 and 4, and this gap is not filled by any strata shown in any of the sections at Dundry. In order to make the sequence complete, strata laid down during the *niortensis*-*Humphriesiani* hemeræ should be present.<sup>2</sup>

Another interesting fact—and one of economic importance—about this section is the great attenuation, together with change in character, of the deposit contemporaneous with the freestone of the quarry near the church. The freestone deposit is only represented at this Northern Main-road quarry by Bed 4, consisting of some thin-bedded limestones about 4 feet in thickness. The decrease will be best appreciated by consulting the plotted diagram, p. 695.

Still proceeding in an easterly direction, the next exposure is found near East Dundry, where the Ironshot Oolite crops out on the hillside west of the village, but only the following very general details have been obtained:—

#### SECTION V.—*East Dundry Village.*

	1. The 'upper beds' crop out by the roadside in the village.	
SAUZEI.	2. 'The Ironshot Oolite.'	} These rocks crop out in the bank near a rough path.
WITCHELLIE.	3. The Upper White Ironshot.	
SONNINIE.	4. The Lower White Ironshot.	
(DISCITE TO AALENSIS.)	5. The lower stone beds. (See general section, Table IV., facing p. 696.)	} These are hidden from view. Estimated thickness:—
DUMORTIERIE.	6. <i>Dumortieria</i> -beds:—Stiff clays with grey sandstone-bands by 'the Rookery' and above 'Spring Farm.'	} 55 0
(DISPANSI TO BIFRONTIS.)	7. An isolated block of the <i>bifrons</i> -beds—a pinkish stone, coarsely ironshot. <i>Har-</i>	
FALCIPERI.	<i>poceras</i> sp.	
	8. Yellowish clay.	
	9. Pinkish-grey earthy stone. <i>Pseudotioceras</i> sp. 5 inches.	} 5 6
SPINATI AND ? MARGARITATI.	10. Strongly ironshot, somewhat variable, massive stone-block, with belemnites, <i>Pseudopecten æquivalvis</i> , <i>Terebratula punctata</i> , and <i>Ostrea</i> in the lowermost 2 feet .....	

*Note.*—The Marlstone, where it crops out on the opposite side of the valley, contains *Amaltheus margaritatus* and *Rhynchonella tetraedra*.

There are three ironshot beds at different horizons—Nos. 2, 7, and 10,—but they are all very different, both in lithological characters and in the fossils which they contain. This is a matter of some importance.

<sup>1</sup> See p. 711.

<sup>2</sup> See 'The Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 500, section of Frogden Quarry.



The Marlstone Rock crops out in the bank of Spring Farm rick-yard, in the middle of East Dundry, and as it forms a small feature it may be traced along the valley below the exposure of the Ironshot Oolite. A measure with the level yielded 70 feet, separating these two well-defined rocks. Deducting from this 15 feet, which other sections in the neighbourhood indicate to be the thickness of the stone beds below the Ironshot Oolite, 55 feet are left as the thickness of the *Dumortieria*-clays, and the presumed intervening stone bed (that is, the 'bifrons-bed'). (See this section, Bed 7, and Section I., Beds 27-30.)

A point of very considerable importance is the above-mentioned outcrop of the Marlstone Rock. It is evident that the officers of the Geological Survey mistook this rock, which is an ironshot oolite, for 'the Ironshot' (No. 2)—a bed so noticeable in the last section—whereby they confused the bottom bed of this Section V. with the top, which is 70 feet above it. Then, acting on this supposition, and knowing there would be so much of the 'Inferior Oolite' below the 'Ironshot,' they drew the base-line of the 'Inferior Oolite' somewhat below the outcrop of the Marlstone Rock, with this result—that they have coloured in their map as 'Inferior Oolite' not only areas occupied by what they call 'Midford Sands' or 'Upper Lias' in other districts, not only Middle Lias, but even in all likelihood a part of what they would term Lower Lias. And in this way they have made the Inferior Oolite in places—for these remarks apply to most of the hill—nearly 150 feet thick: that is, from where they draw their line up to the top of the hill. The 'Inferior Oolite' base-line should have been drawn at the base of No. 5, about 15 feet below the highest outcrop of the Ironshot Oolite; whereas it is drawn in the Geological Survey maps some distance below the outcrop of Bed 10—in fact, nearly 100 feet too low down.

Going farther east, we notice on the northern escarpment of the hill above Hill Farm certain exposures of the Marlstone and associated beds giving the following results:—

#### SECTION VI.—Above Hill Farm (A).

		ft. ins.	ft. ins.
VARIABILIS.	1. Pale drab stone. <i>Rhynchonella</i> aff. <i>Moorei</i> .....	0 4	
	2. Purplish argillaceous ironshot stone. Belemnites; <i>Zeilleria</i> aff. <i>Lycetti</i> ...	0 6	
	3. Dense blue rock, derived. <i>Hildoceras bifrons</i> ; lumps of a pinkish stone, ochreous. Belemnites abound .....	0 3	
SPINATI.			1 1
	4. Marlstone Rock .....		2 0

In this section a deposit laid down during the *variabilis* hemera, containing derived fossils of the *bifrontis* hemera, rests directly upon the Marlstone. In the next section, obtained from tumbled blocks on the hillside, it does not.

SECTION VI A.—*Above Hill Farm (B).*  
(The point almost immediately south.)

		ft. ins.	ft. ins.
VARIABILIS.	1. Lower <i>Rhynchonella</i> -bed, or next bed below. Pale drab to purplish-brown stone, with few scattered iron grains. Belemnites and <i>Rh.</i> aff. <i>Moorei</i> .....		1 0
BIFRONTIS.	2. Yellowish-drab to purplish-brown stone with many scattered coarse iron grains. Ammonites and belemnites. ....		0 8
FALCIFERI.	3. Dense pink stone, small belemnites ...	0 2	
	4. Dense purplish-grey stone .....	0 1	
SPINATI.	5. Marlstone Rock. Yellowish - brown, crystalline, richly oolitic rock, with <i>Pseudopecten æquivalvis</i> , a large <i>Gryphæa</i> or <i>Ostrea</i> , and large belemnites .....		0 3
			1 5

The next section, taken from slightly shifted blocks on the hill-side, gives the following details concerning the Marlstone.

SECTION VI B.—*Above Hill Farm (C).*

		ft. ins.
SPINATI.	1. Marlstone Rock. Massive ironshot; <i>Belemnites</i> , <i>Gryphæa</i> , <i>Ostrea</i> , <i>Pseudopecten æquivalvis</i> .....	2 9
MARGARITATI?	2. Dull, brownish, laminated, but massive, quite unfossiliferous sandstone .....	1 6

There are no sections open at Maes<sup>1</sup> Knoll, and it was necessary to make excavations at suitable places. The next section shows one made on the western flank of the hill or promontory.

SECTION VII.—*Maes Knoll (the eastern end of Dundry Hill).*  
*The western side, just south of the Tump.*

		ft. ins.	ft. ins.
	A gentle grass-covered slope from the top of the hill, concealing rock .....		6 0
GARANTIANÆ.	1. Yellowish limestone thickly speckled with iron grains. <i>Limatula gibbosa</i> , <i>Acanthothyris spinosa</i> , <i>Montlivaltia lens</i> .....	1	4
	2. Pale grey, crystalline limestone with numerous, but irregularly distributed, large, subangular iron grains, and with small lumps of a bluish-grey sandstone nearly at the top. There are also in this bed irregular chimney-like excavations filled with a soft cream-coloured stone containing crowded, very fine iron grains; also <i>Montlivaltia</i> , <i>Acanthothyris spinosa</i> , <i>Limatula gibbosa</i> , <i>Ctenostreon pectini-</i>		

<sup>1</sup> *Maes*, in Welsh, means 'a plain, an open field,' and such a description exactly applies to this elevated, almost isolated, flat tableland.

SECTION VII. (*continued*).

	ft.	ins.	ft.	ins.
GARANTIANÆ ( <i>cont.</i> ).				
<i>forme</i> , <i>Pholadomya</i> sp., <i>Trigonia</i> sp., were found in these excavations or in the film of this matrix on the top of the bed. <i>Actæonina</i> , sp., was found in a tube perforated in the crystalline limestone .....	0	5		
3. 'The Conglomerate-bed.' Pale grey, crystalline limestone containing many derived lumps of a bluish-grey sand- stone, generally bored by <i>Lithodomi</i> , and many more irregularly-shaped lumps of an oolitic, limonitic ironstone. One flattened boulder of this sandstone, measuring about 2' 10" × 14" × 3", considerably bored by <i>Lithodomi</i> which remain in it, lay in the upper part of the bed; <i>Astarte Manseli</i> , <i>Myoconcha</i> <i>crassa</i> , <i>Trigonia</i> aff. <i>costata</i> , <i>Limatula</i> <i>gibbosa</i> , <i>Gouldia ovalis</i> , <i>Cucullæa</i> sp., <i>Opis lunulatus</i> , <i>Ostrea</i> sp., <i>Pecten</i> sp., <i>Lima</i> sp., <i>Pseudomelania coarctata</i> , <i>Cerithium subscalariforme</i> , <i>Ataphrus</i> <i>obtus</i> , <i>A. Labadyei</i> , <i>A.</i> sp., <i>Trochus</i> <i>biarmatus</i> , <i>Natica</i> sp., <i>Belemnites</i> sp., <i>Parkinsonia</i> cf. <i>Garantiana</i> , <sup>1</sup> and <i>Strophodus</i> sp., are indigenous. There are derived fragments of <i>Grammoceras</i> aff. <i>aalense</i> ; much- rolled fragments of <i>Hildoceratidæ</i> , presumably <i>Grammoceras</i> spp., and fragments of <i>Dumortieria</i> , mostly showing a matrix of bluish-grey sand- stone .....	0	6	2	3
DUMORTIERIÆ. 4. Compact, bluish-grey, argillaceous sand- stone in two beds. It contains frag- ments of two or three species of coarsely and finely costate <i>Dumortieria</i> .....	1	0		

Immediately above the *Dumortieria*-beds lies the remarkable conglomerate-bed formed during the *Garantiana* hemera—specimens of *Parkinsonia* cf. *Garantiana* having been found in it. Here, then, is a case of very noticeable non-sequential deposition, denudation being presumably the agency which has removed whatever strata may have been deposited; and in all probability, considering the short distance,—for the Ironshot Oolite is found in an arable field only 7 furlongs to the west—there was originally at Maes Knoll a sequence of deposits similar to that found at the Main-road quarries and at Rackledown (see Sections IV., IX., & X.).

This denudation, no doubt, was in progress partly during Bajocian time, and therefore it was contemporaneous with what was called 'Bajocian denudation' by one of us.<sup>2</sup> But it is evident

<sup>1</sup> Slightly more umbilicate, a little more compressed.

<sup>2</sup> S. S. Buckman, 'The Bajocian of the Mid Cotteswolds,' Quart. Journ. Geol. Soc. vol. li. (1895) p. 431.

that the progress of erosion was continued into Bathonian time, and that the conglomerate-bed of Maes Knoll was largely formed out of materials derived from what was really a post-Bajocian or Bathonian denudation.

The next section shows the Marlstone and associated beds; and by measuring with the level to the conglomerate-bed of the preceding section the thickness of the *Dumortieria*-clay is approximately ascertained. This deposit is found to be of nearly similar thickness at Maes Knoll to what it is at the western end of the hill.

SECTION VII A.—*Maes Knoll. 70 yards east of the Spinney below the Tump.*

		ft.	ins.	ft.	ins.
GARANTIANÆ.	1. Conglomerate-bed.				
DUMORTIERIÆ.	2. Clay and sandstones..... about	.....		60	0
DISPANSI.	3. Grey, argillaceous stone with widely scattered iron grains .....	0	6		
	4. Greyish-drab, argillaceous stone with scattered iron grains. Belemnites ...	0	5		
		—		0	11
STRIATULI?	5. Purplish-brown to drab, speckled stone with belemnites, shell sections, ammonites with a drab matrix .....	.....		0	7
VARIABILIS.	6. Upper bed of blue rock with brown iron grains and ferruginous lumps .....	0	5		
	Lower, blue rock, scattered iron grains, ferruginous lumps, and lumps of a dense pink stone .....	0	2		
		—		0	7
SPINATI.	7. 'Marlstone Rock.' Very dense rock, a ferruginous oolite. <i>Pseudopecten æquivalvis</i> . A grey sandy rock forms the lower 4 inches of this bed, while the upper 4 inches is richly ironshot, with red and yellow tints .....	.....		1	7
MARGARITATI?	8. Grey, thinly laminated, but massive unfossiliferous sandstone, found apparently at its base .....	.....		1	6

The next section is on the eastern side of the hill, and it is remarkable for one thing—that the Marlstone is absent; so that at this, the extreme eastern point, was found a condition of things similar to that which obtains at the western end.

SECTION VII B.—*Maes Knoll, on the eastern flank, overlooking New Barn Farm. Special excavation.*

		ft.	ins.	ft.	ins.
DUMORTIERIÆ.	1. Stiff, greenish clay with harder beds of argillaceous sandstone, extending up the hill.				
	2. Pale yellowish-green sandstone, fragments of <i>Dumortieria</i> aff. <i>prisca</i> , <i>D.</i> aff. <i>radians</i> , <i>Hudlestonia</i> aff. <i>serriidens</i> .....	0	6		
	3. Bluish and yellowish arenaceous clay ...	2	6		
		—		3	0

		ft.	ins.	ft.	ins.
DISPANSI.	4. Yellowish, argillaceous sandstone; <i>Hammotoceras</i> , sp. nov., involute with helmet-shaped whorls.....	0	5		
	5. Bluish arenaceous clay .....	1	0		
	6. 'The Upper <i>Rhynchonella</i> -bed.' Somewhat yellowish-brown, iron-speckled stone. <i>Rhynchonella</i> aff. <i>Moorei</i> .....	0	5		
	7. Brown, irregularly iron-speckled, tough, earthy stone. <i>Grammoceras Struckmanni</i> in the upper half, and canaliculate belemnites. <i>Haugia</i> aff. <i>Eseri</i> , <i>Gramm. striatulum</i> , and numerous cylindrical belemnites at the base and about 2 inches up. <i>Rhynchonella</i> aff. <i>Moorei</i> in the bed. Thickness 6 inches.	0	4		
STRIATULI. (2 inches of bed 7; the other 4 inches of the 6'' belongs to <i>Dispansi</i> .)		0	2	2	2
	8. Dark brown, coarse, but irregularly ironshot stone—the grains generally crowded. <i>Grammoceras striatulum</i> not uncommon; <i>Gr.</i> cf. <i>Sæmanni</i> 1 specimen; belemnites .....	0	6		
VARIABILIS.	9. Stone with similar matrix. Fragments of several species of the costate tuberculate <i>Haugia</i> aff. <i>jugosa</i> . One fragment of a large, strongly costate species of the <i>Lillia</i> <i>Lilli</i> type, <i>Zeilleria</i> aff. <i>anglica</i> (between <i>Lycetti</i> and <i>anglica</i> ).....	0	3		
	10. Stone with similar matrix. <i>Haugia</i> aff. <i>jugosa</i> , fairly large and fairly frequent, but in very poor condition. Large belemnites .....	0	2½		
	11. 'The Lower <i>Rhynchonella</i> -bed.' Stone with similar matrix, <i>Haugia</i> sp., <i>Rh.</i> aff. <i>Moorei</i> <sup>1</sup> not uncommon. This bed also contains the following derived fossils, showing a pink matrix, and more or less coated with iron oxide:— <i>Hildoceras bifrons</i> , and especially the thin form; <sup>2</sup> <i>Dactylioceras</i> , spp. <sup>3</sup> Fragments of <i>Harpoceras</i> aff. <i>falci-ferum</i> ; also irony lumps .....	0	4		
	12. Compact, blue, irregularly ironshot limestone with iron lumps, bearing worm-tracks. Derived lumps of a pink matrix, and derived fossils—the same as in the overlying bed. Belemnites, smooth Pectens, <i>Rhynchonella</i> .....	0	4		
				1	1½
BIFRONTIS.	13. Compact argillaceous limestone, blue and ironshot for the upper 5 inches,				

<sup>1</sup> It is a form different from the *Rhynchonella* in Bed 6.

<sup>2</sup> See pl. xxii. figs. 30 & 31, in 'Monogr. Inf. Ool. Ammonites,' by S. S. Buckman.

<sup>3</sup> Three species:—1. Cf. *Desplacei*, d'Orbigny, pl. cvii.; *Dayi*, Reynès, 'Géol. & Paléont. aveyronnaises,' pl. v. fig. 7. 2. Cf. *subarmatum*, Dumortier, vol. iv. pl. xxviii. fig. 6. 3. Cf. *commune*, Sowerby, pl. cvii., but less coarsely costate.

SECTION VII B (*continued*).

	ft.	ins.	ft.	ins.
BIFRONTIS ( <i>cont.</i> ). and pink, not ironshot, for the lower 3 inches. The blue part contains: <i>Hildoceras bifrons</i> , <i>Dactylioceras</i> <sup>1</sup> and <i>Harpoceras falciferum</i> coated with iron oxide, together with derived iron lumps; also <i>Rhynchonella</i> . The pink portion has a matrix similar to that of the derived fossils in the overlying beds, and it contains <i>Harpoceras falciferum</i> & <i>H. exaratum</i> . Thickness 8 inches .				
FALCIFERI lower 3 inches.	0	3	0	5
14. Pink clay. <i>Harpoceras</i> aff. <i>Strangwaysi</i> , <i>Pseudolioceras</i> ? sp. ....	0	6		
15. Pale drab, earthy stone .....	0	5		
16. Pinkish-drab, ironshot, earthy stone with lumps of greenish stone bored by <i>Lithodomi</i> , and covered with iron oxide, <i>Dactylioceras</i> and belemnites ...	0	9		
			1	11
17. Greenish clay, about 34 feet proved, without a sign of Marlstone or of any hard rock.				

The fossiliferous strata associated with the 'bifrons-beds' are interesting for the regular sequence of different ammonites. There are, at the eastern end of the hill, thin fossiliferous deposits laid down during the *dispansi*, *striatuli*, *variabilis*,<sup>2</sup> and *bifrontis* hemeræ, comparable in amount to those found at the western end. During the earlier portion of the *variabilis* hemera local denudation was evidently in progress, as is shown by the condition of the deposits numbered 15 and 16; the *bifrons*-beds have evidently been broken up and redeposited just before or during the time of *variabilis*.

Immediately above the thin stone beds occurs a considerable argillaceous deposit, with a species of *Hammatoceras* at the base, and species of *Dumortieria* in its main mass. This is what we have called the 'Dumortieria-beds,' and it is the same deposit as that which we found at the western end of the hill. It is a noticeable series, and we shall have something further to mention concerning it (see p. 707).

<sup>1</sup> Two species:—1. Cf. *commune*, Sowerby, pl. cvii., but less coarsely costate. 2. Cf. *annulatum*, Sowerby, pl. cxxii. fig. 5 (the coarser-ribbed of his two forms, but thinner).

<sup>2</sup> It may be noted that although the deposits are said to have been laid down during three hemeræ, *Dumortieria*, *dispansi*, and *striatuli*, the exact ammonite sequence found by S. S. Buckman to obtain over a large extent of country is as follows:—

6. *Dumortieria*.
5. *Hammatoceras insigne*, with other species of the genus.
4. *Grammoceras dispansum*.
3. *Grammoceras Struckmanni*, and allied species.
2. *Haugia Eseri* (with occasional species of No. 1).
1. *Grammoceras toarcense* and *Gr. striatulum*, common.

As an actual matter of fact, no specimens of *Grammoceras dispansum* have been found at Dundry Hill.

It is now necessary to return, in order to study some sections along another line of country.

Southward from Dundry Church are two exposures: one is Barns Batch Quarry, at the bend in the road to Littleton on the southern flank of the hill; and it yields the following section:—

#### SECTION VIII.—*Barns Batch.*

	ft.	ins.
Pale grey, crystalline, coarse-textured limestone and ragstone massively bedded, but somewhat rubbly in places .....	19	0

*Note.*—Here were obtained corals, *Terebratula* aff. *globata*, & *Ostrea*, the same species as one that was found in the Coralline of the main-road quarries.

The other section is about two fields eastward in a small clump of trees. On the 6-inch Ordnance map it is marked as a 'Gravel Pit.' We have called it 'Barns Batch Spinney.'

#### SECTION VIII A.—*Barns Batch Spinney.*

	Upper Beds.	ft.	ins.	ft.	ins.
	To top of hill, showing at intervals beds like those at Barns Batch .....			45	0
	1. Irregularly, thinly laminated, white crystalline limestone with numerous corals, large <i>Thamnastræa</i> , small <i>Ostrea</i> , <i>Pecten</i> sp., <i>Lithodomi</i> , <i>Cidaris Fowleri</i> , <i>Terebratula</i> sp., <i>Rhynchonella</i> sp. ....			5	0
	Lower Beds.				
SONNINIAE.	2. Irregularly-bedded limestone, of a pale pinkish grey, with minute iron grains and sparry shells. A line of large smooth ammonites ( <i>Sonninia fissilobata</i> ?) 5 to 6 inches from top, <i>Lima Etheridgii</i> , <i>Myacites jurassi</i> , <i>Ctenostreon pectiniforme</i> , <i>Trigonia striata</i> (cast), <i>Pecten</i> sp., <i>Sphæroceras Brocchi</i> , <i>Belemnites</i> , .....			1	2
	hardly separable from				
DISCITÆ.	3. Laminated sandy limestone-parting, forming an irregular and local divisional line at this level. <i>Lima Etheridgii</i> , <i>Myacites jurassi</i> .....			6 to 7	
	4. Compact, nodular, greyish limestone, with irregular earthy partings between the nodular lumps; a large smooth and a coarsely spinous <i>Sonninia</i> , <i>Hyperlioceras</i> sp., <i>Pecten</i> sp., <i>Gresslya abducta</i> , <i>Myacites jurassi</i> . ....			8 to 9	
	5. Pale grey, compact, nodular limestone with earthy partings, in four blocks...	1	11		3

SECTION VIII A. (*continued*).

		ft.	ins.	ft.	ins.
CONCAVI.	6. Pale yellowish, compact limestone, with scattered iron grains, more regularly bedded than No. 5, with occasional earthy partings: <i>Lioceras concavum</i> , <i>Modiola Sowerbyana</i> , <i>Terebratula Eudesi</i> .....	.....		3	9
BRADFORDENSIS AND MURCHISONÆ.	7. Grey to brown, sandy and crystalline limestone with small, scattered iron grains; very few fossils. A large smooth ammonite and <i>Terebratula Eudesi</i> (? <i>shirburniensis</i> ) near the top. ....	.....		4	3

*Note*.—The underlying beds are concealed by the quarry talus. The dip of the beds here is nearly due east at about 3°.

The deposits marked Nos. 2–4 can be correlated in a general way, without any difficulty, with the deposits shown in other sections. No. 2 is the Lower White Ironshot bed on the horizon of *fissilobata-ovalis*, the time of its deposition being that of the ‘*Sonninix*’ hemera. Our opinion of the time of the deposition of the other beds, and consequently of their correlation, is shown in the margin.

It is important to notice that there is no Ironshot here, nor is the *Witchellia*-bed present—these beds have, presumably, been removed by denudation. Therefore bed No. 1 caps No. 2 non-sequentially. We consider that bed No. 1 is approximately contemporaneous with the Freestone in the large quarry by the church; but we are much puzzled as to the position of the 19 feet of stone at Barns Batch, or of presumably a much greater thickness of deposit above Bed 1 of this section. To the top of the hill on a fairly steep slope above the Spinney there are some 45 feet of rock. Part of the apparent thickness of the rock on this slope might be due to repetition of the beds by step-faults; but we know that at least 20 feet of rock must be present on the evidence of Barns Batch. If the thickness be no more than this, it is possible that all the beds above No. 2 were deposited contemporaneously with the Freestone; but if the thickness be greater, two interpretations present themselves:—(1) There was a considerable thickness of limestone deposited subsequent to the Coralline beds<sup>1</sup>; or (2) all this limestone was deposited before the Coralline beds, and therefore a much greater thickness of a coarser-textured stone was laid down at the south-western portion of the hill, while 20 feet of Freestone were being deposited near the church, and 4 feet of limestone in the northern roadside quarry.

The solution of the question may become a matter of economic importance (see p. 710), and it is certainly of scientific interest—especially if the first supposition prove correct.

Another direction from Dundry Church may be taken, namely, S.E., to a section on the main road, at the edge of the southern escarpment. The following details have been obtained:—

<sup>1</sup> In that case it is quite possible that the Barns Batch beds may be a calcareous deposit contemporaneous with the argillaceous strata called ‘Fullers’ Earth’ in other places, as is the case with the ‘Calcaire de Caen’ in Normandy.



SECTION IX.—*The Southern Main-road Quarry—east of the Chew Stoke road on the edge of the southern escarpment.*

		ft.	ins.
CORALLINE BEDS.	1. Coralline limestone mixed with clay, more stony above, more marly below. <i>Zeilleria Waltoni</i> , <i>Aulacothyris carinata</i> , <i>Rhynchonella subtetraedra</i> , <i>Ostrea</i> sp., <i>Lima</i> sp. ....	5	0
EQUIVALENT OF FREESTONE.	2. Grey, slightly ironshot stone in regular beds and crystalline.....	3	4
GARANTIANÆ.	3. Grey, crystalline, somewhat ironshot 'ragstone.' <i>Astarte Manseli</i> , <i>Rhynchonella subtetraedra</i> , <i>Aulacothyris carinata</i> . Corals .....	0	10
SAUZEI.	4. Hard ironshot limestone with planed-off top. The fossil bed, with numerous <i>Sonninia</i> and <i>Stephanocera</i> , and other fossils generally agreeing with those met with in the same bed in the Northern Main-road Quarry .....	1	0
WITCHELLIÆ.	5. Whitish, ironshot limestone, where exposed much broken up by the weather; when quarried 2 or 3 inches of this adheres to the overlying bed. The upper part is best for <i>Witchellia</i> . <i>Sonninia</i> cf. <i>fissilobata</i> 6 inches from top.....	0	8
	6. Soft earthy stone with <i>Sonninia</i> of the <i>ovalis</i> -type and other <i>Sonninia</i> , <i>Ctenostreon pectiniforme</i> , <i>Mycites</i> .....	1	0
DISCITÆ. <sup>1</sup>	7. A similar limestone to base of quarry.....	0	6

## SECTION IX A.

*The following details were taken of the beds in the south-eastern corner of the quarry by E. Wilson in the year 1887. The pit is now nearly filled up.*

	ft.	ins.
1. Rubbly earthy oolite .....	0	6
2. Compact light-coloured limestone with small iron grains .....	0	5
3. Irregular clay parting.		
4. Limestone, purplish-grey, compact, with small scattered iron grains .....	0	4
5. Clay parting .....	0	3
6. Light-coloured, finely crystalline limestone with small, scattered iron grains .....	0	4
7. Light-grey, finely crystalline limestone with ochreous nodules, rather loose and rubbly. <i>Terebratula</i> , <i>pectens</i> , <i>ammonites</i> , <i>belemnites</i> .....	1	0
8. More solid, pinkish limestone, compact and unfossiliferous or nearly so, with more or less thickly scattered ochreous grains in two beds, 8 and 10 inches .....	1	6
9. Hard, subcrystalline, pinkish limestone with scattered ochreous specks .....	0	8
10. Hard, subcrystalline, pinkish-grey limestone with scattered ochreous specks .....	0	7
11. Hard, subcrystalline, grey limestone with scattered ochreous specks .....	0	11
12. Pinkish-grey limestone to base of quarry .....	0	6
	7	0

*Note to Section IX A.*—This is the downward continuation of Section IX., presumably without any noticeable break, so that Bed 1 of Section IX A is

<sup>1</sup> The workmen had obtained specimens of *Hyperlioceras* in the quarry, and they must have come from Bed 7 or below it.

the same as, or just below Bed 7 of Section IX. The *Terebratula* in Bed 7 is presumably *T. cortonensis*; and the ammonites are probably *Hyperlioceras*, or allies of *Lioceras concavum*. The four or five lowermost beds were presumably deposited during the *Murchisonæ* hemera, and have probably yielded some of the fossils of that date now in the Bristol Museum. Compare with Sect. X., Bed 5.

The correlation of the deposits of Section IX. is easy—it is a repetition of the northern roadside quarry. The noticeable points are that the Ironshot and the *Witchellia*-bed are present, and that there is only a thin deposit separating the Coralline from the Ironshot, so that there are no Freestone beds below the Coralline to be expected in this part of the hill.

The last section which we have to mention is near Rackledown Farm, situated on the south-western corner of the southern spur, which is separated from the main mass of the hill by the valley below East Dundry.

#### SECTION X.—*Rackledown*<sup>1</sup> Farm.

		ft.	ins.	ft.	ins.
CORALLINE BEDS.	1. Pale greenish-yellow coralline rubble. <i>Aulacothyris carinata</i> ..... about	.....		4	0
FREESTONE EQUIVALENT.	2. Thin-bedded, white limestone with marl..... about	.....		4	0
SAUZEI and perhaps WITCHELLIÆ.	3. 'The Ironshot.' <i>Sphæroceras Sauzei</i> , and a number of species of the <i>Sonninia propinquans</i> -type. Probably also including the bed at the base of the Ironshot, from which so many species of <i>Witchellia</i> come. This quarry has yielded a good series, but they are difficult to obtain <i>in situ</i> ..... about	.....		3	0
SONNINIE to CONCAVI.	4. Beds below the Ironshot. Several beds of pinkish-grey limestone with marly partings. <i>Hyperlioceras</i> about 3 feet 6 inches from the base ..... about	.....		5	6
MURCHISONÆ.	5. Somewhat irregularly bedded and cross-jointed, very dense, pinkish-red, crystalline limestone with small scattered iron grains, getting more compact upwards. The top of the bed is somewhat planed off, and covered with ferruginous nodular lumps. <i>Zeilleria anglica</i> , <i>Rhynchonella Stephensii</i> ?, <i>Myacites</i> aff. <i>jurassi</i> <sup>2</sup> ..... 4 9	4	9		
	6. Tough crystalline limestone, yellowish grey, with scattered iron grains ..... 1 7	1	7		
	7. Earthy limestone with scattered iron grains, with interwedgings of irregular, compressed, ironshot, sandy clay. <i>Ludwigia</i> cf. <i>obtusa</i> on spoil-heap with matrix similar to this bed ..... 0 5	0	5		
				6	9
OPALINI?	8. Pinkish-grey, somewhat ironshot, somewhat crystalline limestone. <i>Pholadomya fidicula</i> ..... 2 8			2	8

<sup>1</sup> On the 6-inch Ordnance map spelt 'Rattledown.'

<sup>2</sup> From this bed, judging by matrix, a fine *Ludwigia* aff. *obtusa*, Quenstedt, in the Bristol Museum, was obtained; also the specimens of *Cirrus*.

Bed 5 is hard and massive—very distinct from the rubbly condition to which the other rocks of this section have been reduced. It was certainly deposited during the *Murchisonæ* hemera, and part of it, perhaps, during the *bradfordensis* hemera; but we have no evidence on the latter head.

Of the remaining deposits it will be noticed that the Ironshot extends to this quarry, and that the equivalent of the Freestone is very thin; but of the beds generally we are unable to give any precise details owing to the very tumbled condition in which the strata are presented. There is enough evidence to show that the series (Nos. 1-4) is an approximate repetition of what obtains in the main-road quarries.

Such are the sections which we have examined, and upon these and the rocks which they illustrate we have now to make further remarks under the following headings.

#### IV. THE DEVELOPMENT OF THE DUNDRY STRATA.

In order to show the development of the various beds as well as their geographical extension, we have arranged the quarry and other sections according to the three lines of country: W. to E., S.W. by S. from Dundry Church, and N.W. to S.E.; and under the names of the different sections, taken in this order, we have placed the thickness of deposit which was formed during the several hemeræ—so far as we have been able to apportion it.

The results stated in figures in the first of the accompanying Tables (I.-IV) we have plotted to scale in a diagram (p. 695). Concerning this diagram we would make the following remarks:—

We have taken the base of the *bifrons*- and associated beds as a base-line.

We have found, as the result of numerous trials with the level and many investigations, a thickness for the *Dumortieria*-beds of 50 feet at the western end, 55 feet at East Dundry, and 60 feet at Maes Knoll.

We have found the Marlstone only in the eastern portion of the hill, east of the main road, and no signs of it west of the main road. It appears to be a bed which fluctuates considerably in thickness; but perhaps the fluctuation shown in the diagram may be partly attributed to the imperfect state of our exposures. We know that it fails altogether at the eastern end of the hill, and also at the western end; but it must be remembered that the place of its westerly disappearance, as shown in our diagram, is only conjectural.

We find at Maes Knoll that the Bathonian rests directly upon Toarcian—*Dumortieria*-beds, and that no deposits of Aalenian or Bajocian age are present.

*Note.*—The suggestion of false-bedding in the Freestone, and that only its top bed continues above the Ironshot, must not be attributed to the authors. It is an oversight in the representation by lines of the colour of the original diagram

TABLE I.—WESTERN END OF DUNDRY HILL TO MAES KNOLL (WEST TO EAST).

	West of Hill by Castle Farm.	Clements' Freestone Yard.	Freestone Quarry; Dundry Church.	The North Main-road Quarry.	Rackledown Farm.	East Dundry.	Above Hill Farm (A).	Above Hill Farm (B).	Above Hill Farm (C).	Maes Knoll West.	Maes Knoll East.
	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.
Coralline Beds.....	.....	.....	7 6	4 6	4 0	.....	.....	.....	.....	.....	.....
Freestone .....	.....	.....	17 9	4 0	4 0	.....	.....	.....	.....	6 0	.....
Hemera :—	0 5	1 0	.....	.....	.....	.....	.....	.....	.....	2 3	.....
<i>Garantiane</i> .....	.....	.....	.....	1 0	3 0	.....	.....	.....	.....	.....	.....
<i>Sanzei</i> .....	.....	.....	.....	1 2	.....	.....	.....	.....	.....	.....	.....
<i>Witchellie</i> .....	.....	.....	.....	1 5	.....	.....	.....	.....	.....	.....	.....
<i>Sonnina</i> .....	7	2 1	.....	2 5	5 6	.....	.....	.....	.....	.....	.....
<i>Discoia</i> .....	1 4	1 10	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Concavi</i> .....	3 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Bradfordensis</i> .....	.....	.....	.....	.....	6 9	15 0	.....	.....	.....	.....	.....
<i>Murchisonae</i> .....	6 4	.....	.....	.....	2 8	.....	.....	.....	.....	.....	.....
<i>Opalini</i> .....	1 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Aalenis</i> .....	0 3	.....	.....	.....	.....	.....	.....	.....	.....	60 0	2 2
<i>Dumortieria</i> .....	50 0	.....	.....	.....	.....	.....	.....	.....	.....	0 11	0 8
<i>Dispani</i> .....	0 4	.....	.....	.....	.....	.....	.....	.....	.....	0 7	1 2
<i>Striatuli</i> .....	0 2	.....	.....	.....	.....	55 0	1 1	1 0	.....	0 7	0 5
<i>Variabilis</i> .....	.....	.....	.....	.....	.....	.....	.....	0 8	.....	.....	.....
<i>Bifrons</i> .....	0 2	.....	.....	.....	.....	.....	.....	0 3	.....	.....	1 11
<i>Falcifer</i> .....	0 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
<i>Spinati</i> .....	.....	.....	.....	.....	.....	5 6	2 0	1 5	2 9	.....	.....
<i>Margaritati</i> .....	.....	.....	.....	.....	.....	.....	.....	.....	1 6	1 6	.....

*Longitudinal Diagrammatic Section of Dundry Hill.*  
 [Horizontal scale: 2 inches=1 mile; vertical: 1 inch=30 feet.]

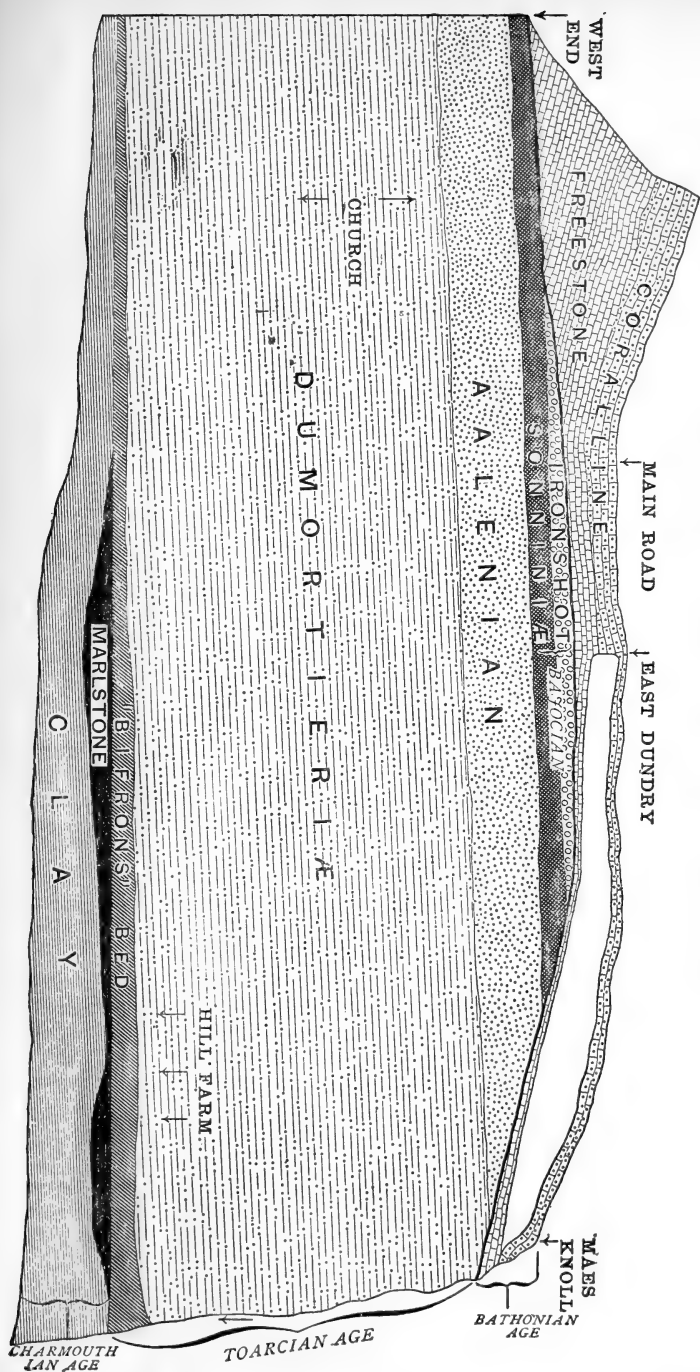


TABLE II.—DUNDRY CHURCH TO BARNS BATCH SPINNEY  
(SOUTH-WEST BY SOUTH).

	Western End, Church and Clements' Yard.		Barns Batch Spinney.	
HEMERA:—	ft.	ins.	ft.	ins.
? (Coralline) .....	7	6	} 50	0
? (Freestone) .....	17	9		
<i>Garantiana</i> .....	1	0		
<i>Sauzei</i> .....				
<i>Witchellia</i> .....				
<i>Sonninia</i> .....	2	1	1	2
<i>Discitæ</i> .....	1	10	3	3 <sup>1</sup>
<i>Concavi</i> .....	3	6	3	9 <sup>1</sup>
<i>Bradfordensis</i> .....	} 6	4	4	3 <sup>1</sup>
<i>Murchisonæ</i> .....			Base hidden.	
<i>Opalini</i> .....				
<i>Aalensis</i> .....	1	6		

<sup>1</sup> The actual thickness deposited during each hemera at this locality is, on account of the condition of the exposure, somewhat conjectural.

TABLE III.—DUNDRY CHURCH TO RACKLEDOWN (SOUTH-EAST).

	Western End, Church and Clements' Yard.		Dundry Main Road, Southern Quarry.		Rackledown Farm.	
HEMERA:—	ft.	ins.	ft.	ins.	ft.	ins.
? (Coralline) .....	7	6	5	0	4	0
? (Freestone) .....	17	9	3	4	4	0
<i>Garantiana</i> .....	1	0	0	10		
<i>Sauzei</i> .....			1	0	} 3	0
<i>Witchellia</i> .....			0	8		
<i>Sonninia</i> .....	2	1	1	0		
<i>Discitæ</i> .....	1	10			} 5	6
<i>Concavi</i> .....	3	6				
<i>Bradfordensis</i> .....	} 6	4				
<i>Murchisonæ</i> .....					} 6	9
<i>Opalini</i> .....						
<i>Aalensis</i> .....	0	3			} 2	8
<i>Dumortieria</i> .....	50	0				
<i>Dispani</i> .....	0	4				
<i>Striatuli</i> .....	0	2				
<i>Bifrontis</i> .....	0	2				
<i>Falciferi</i> .....	0	2				

We find at East Dundry the full sequence of Aalenian deposits, and of Bajocian until the *Sauzei* hemera—the Ironshot Oolite. The top of this Ironshot is eroded, and from this eroded top to the Marlstone is the same distance as from the eroded top of the *Dumortieria*-beds to the Marlstone at Maes Knoll. Consequently the Bajocian and Aalenian beds must successively disappear between East Dundry and Maes Knoll, presumably on account of denudation; but where, can be suggested only approximately on our

TABLE IV.—THE SEQUENCE OF DEPOSITS AT DUNDY HILL.

Chronological Terms. <sup>1</sup>			Deposits made during the stated times.	Stratigraphical Terms employed until recently.
Epochs.	Ages.	Henere. <sup>2</sup>		
		<p>Post-GARANTIANÆ. (The exact date is uncertain.)</p> <p>DIKATON.</p>	<p>Possibly the Barns Batch strata. (See Sections VIII. &amp; VIII A., and remarks thereon.)</p> <p>The Coralline beds: a coralliferous stone mixed with much marl, occupying the highest parts of the hill; its upper portion removed by recent denudation. (Section III. Beds 1 &amp; 2.)</p> <p>The Dundee and a local deposit of <i>Adams of anomalia</i> and <i>Adams of anomalia</i>.</p>	
EO-JURA			<p>The Blue Ironshot—the <i>Rhynchonella</i>-beds or the <i>bifrons</i>-beds. (Section VII n. Beds 4-13.)</p>	
	TOARCIAN.			Upper Trias generally.
		VARIABILIS.		





TABLE IV.—THE SEQUENCE OF DEPOSITS AT DUNDY HILL.

Chronological Terms. <sup>1</sup>		Deposits made during the stated times.	Stratigraphical Terms employed until recently.
Epochs.	Ages.		
NEO-JURASSIC.	Hemera. <sup>2</sup>		
	Post-GARANTIANÆ. (The exact date is uncertain.)	Possibly the Bams Batch strata. (See Sections VIII. & VIII A., and remarks thereon.)  The Coralline beds: a coralliferous stone mixed with much marl, occupying the highest parts of the hill; its upper portion removed by recent denudation. (Section III. Beds 1 & 2.)  The Freestone: a local deposit of stone of economic value, passing laterally into thin beds of no value, except as inferior roadstone, which we have called 'Freestone equivalent.' (Section III. Beds 3 & 4; Section IV. Bed 4.)	<i>Parkinsoni</i> -zone.
	GARANTIANÆ.	A thin deposit not always to be detected (Section II. Beds 1 & 2), = the Conglomerate-bed of Maes Knoll (Section VII.).	
	NORFENSIS.	No deposits of this date have been found on the hill.	
	HUMPHRIESIANI.	The same as above. If any deposit were made, it was removed by the denudation which took place during this or the subsequent hemera.	
	SAUZEI.	The Ironshot: a deposit which the Bajocian denudation has removed from most of the hill. (Section IV. Bed 5.)	<i>Humphriesianus</i> -zone.
	WITCHELLIIÆ.	The Upper White Ironshot—the <i>Witchellia</i> -beds. (Section IV. Bed 6.)	
	SOMNINIÆ.	The Lower White Ironshot—the <i>fossilibata-ovalis</i> horizon. (Section I. Beds 4-8.)	Perhaps considered as <i>Humphriesianus</i> -zone, perhaps as Midford Sands, by earlier authors. Later <i>concaus</i> -beds.
	DISCITE.	The Grey Limestone and Marl-beds—the <i>discites</i> - and <i>concaus</i> -beds—the <i>Terebratula Eudesi</i> -beds. (Section I. Beds 9-18.)	
	CONCAVI.		
	BRADFORDENSIS.	The hard irony beds exposed as massive rock at Rackle-down Quarry. (Section X. Beds 5-7.)	The <i>Murchisonæ</i> -zone was not recognized as occurring at Dundy by earlier geologists. Later <i>Murchisonæ</i> -zone.
	MURCHISONÆ.		
	OPALINI.	The bottom beds (of stone). (Section I. Beds 24 & 25.)	
	AALSENSIS.		
EO-JURASSIC. <sup>3</sup>	DUMORTIERIÆ.	The Upper Clay beds—the <i>Dumortieria</i> -beds. (Sections VII A. Bed 2, VII B. Beds 1-3.)	
	DISPANSI.		
	STRIATULLI.		
	VARIABILIS.	The Blue Ironshot—the <i>Rhynchonella</i> -beds or the <i>bifrons</i> -beds. (Section VII B. Beds 4-13.)	Upper Lias generally.
	BIFRONTIS.		
	FALCIPERI.	The Pink Beds—the Upper Lias. (Section VII B. Beds 13-16.)	
	SPINATI.		
CHARMOUTHIAN.		The Marlstone. (Section VII A. Beds 7 & 8.)	
		The Lower Clay bed. (Section VII B. Bed 17.)	

<sup>1</sup> [We may explain that the terms 'Bathonian,' 'Bajocian,' etc. are used only as chronological terms to indicate certain 'Ages'; that such 'Ages' are made up of so many hemera; that a hemera is a period of time marked by particular zoological phenomena; and therefore that any group of hemera—an Age—must also be similarly governed in its extent by zoological phenomena. Since, in the present cases, the hemera are governed by the zoological phenomena connected with ammonite species, therefore the Ages must be governed by the phenomena of larger ammonite groups. Hence we use the terms as follows:—

BATHONIAN AGE.	{ Hemera from <i>nortensis</i> onwards up to (?) what is called Oxfordian. (We do not pledge ourselves as to its upper limits.)	{ Zoological phenomena:—Predominance of <i>Parkinsonia</i> and allied genera.
BAJOCIAN AGE.	Hemera: <i>discite</i> to <i>Humphriesian</i> inclusive.	Acme and paracme of <i>Somnina</i> .
AALENIAN AGE.	Hemera: <i>aalensis</i> to <i>concaui</i> inclusive.	{ <i>Isidalgia</i> and allied genera of <i>Hildoceratida</i> .
TOARCIAN AGE.	Hemera: <i>falciperi</i> to <i>Dumortieria</i> .	{ <i>Grammoceras</i> , <i>Hildoceras</i> , and allied genera of <i>Hildoceratida</i> .

Practically the Toarcian and Aalenian Ages correspond to the acme and paracme of the *Hildoceratida*; and at one time S. S. Buckman proposed to call these divisions by the one name Toarcian ('The Cotteswold, Midford, and Yeovil Sands,' Quart. Journ. Geol. Soc. vol. xlv. 1889, p. 461); but subsequently it was found that the length of this Age would be out of all proportion to the length of others. Therefore, acting partly on a suggestion made by Dr. E. Haug, he has adopted the divisions Aalenian and Toarcian, taking note of the zoological phenomenon of the appearance of the *Poly-morphida*—genera *Dumortieria*, etc.—as a break in the predominance of the *Hildoceratida*. Hence the Toarcian Age is brought to a close with the zoological phenomenon of the predominance of the *Poly-morphida*, and the Aalenian, which begins with the renewed predominance of the *Hildoceratida*, continues until the *Somnina* become of greater importance than the *Hildoceratida*—that is, just before the final complete extinction of the *Hildoceratida*.

A nearly completed paper by S. S. Buckman more fully explains these views, and the reasons for their adoption.—August 31st, 1896.]

<sup>2</sup> Concerning this term and the designatory hemeral names, see S. S. Buckman, 'The Bajocian of the Sherborne District,' Quart. Journ. Geol. Soc. vol. xlix. (1893) p. 479, and 'The Bajocian of the Mid-Cotteswolds,' *ibid.* vol. li. (1895) p. 388.

<sup>3</sup> Henry Shuler Williams proposed to distinguish the divisions of an Era (our Epochs) by prefixing the syllables Eo-, Meso-, Neo- when three divisions were required ('Dual Nomenclature in Geological Classification,' Journal of Geology, vol. ii. p. 157: Chicago, 1894).



diagram. However, we have found that the Ironshot rubble occurs in a ploughed field  $\frac{1}{2}$  mile east of Walnut Farm.

West of East Dundry, as before stated, we have found that the Ironshot Oolite does not extend to the freestone-quarry near the church. How far east of that it disappears we can only suggest in the diagram, since there are no data available after passing the northern roadside quarry.

The line of Bajocian denudation consequently runs with a slight easterly rise from the western end of the hill to East Dundry; then it continues practically level for a space, and finally it falls with an easterly dip to Maes Knoll. It is indicated in the diagram by a thick dark line.

The one other point in connexion with this diagram which demands our attention is the rapid easterly attenuation of the Freestone.

#### V. THE STRATIGRAPHICAL SEQUENCE AT DUNDRY HILL.

No one exposure shows the full thickness of the deposits which we have examined, but by the correlation of the various sections a generalized section of the hill is obtained (Table IV).

From this Table it may be seen that there is a break in the due sequence of deposits at Dundry Hill. As a matter of fact, this break in the sequence is least in the middle of the hill; but to the west it is greater, in such wise that strata of the *Garantianæ* hemera rest directly upon strata of the *Sonninæ* hemera; while to the east it is very marked—the strata of the *Garantianæ* hemera lying directly upon those of the *Dumortieræ* hemera.

#### VI. THE FAUNAL SEQUENCE AT DUNDRY HILL.

As Table I. (p. 694) has shown the different deposits which have been laid down at Dundry Hill, together with the dates to which we assign such deposits, it is now possible for us to show in Tables V. & V A. the sequence of faunas which lived during the deposition of the strata in question. In part this list, which claims to be only an approximate record, by no means complete, has been compiled from the results of collecting during the work of noting the different sections; but much of it is based upon our knowledge of specimens collected during previous years by ourselves and by other geologists.<sup>1</sup> We are enabled to state more or less approximately the geological date of the species so collected by observation of the character of the matrix; for it may be seen from our sections that the deposits made during different times are easily recognizable by their lithological characters. Cases of doubt of course occur, and such cases are marked by the placing of a note of interrogation before the generic name.

<sup>1</sup> We are indebted not only to those geologists by whose labours the Bristol Museum has been enriched in the past, but also to those who have done so much work at Dundry Hill in the present, Mr. J. W. D. Marshall, Mr. J. W. Tutchet, Mr. A. Vaughan, B.Sc., and other members of the Bristol Geologists' Association, to whom we owe our best thanks for kindly submitting specimens for our examination.

TABLE V.—THE FAUNAL SEQUENCE AT DUNDRY. [S. S. BUCKMAN.]

Those marked † are type-forms named from Dundry specimens. Those figured from Dundry but not specific types are marked (\*).

HEMERÆ.	CEPHALOPODA.	BRACHIOPODA.
POST-GARANTIANÆ (Coralline and Freestone).		<i>Zeilleria</i> <i>Acanthothyris</i> <i>Waltoni.</i> <i>panacanthina.</i> <i>Terebratula</i> † <i>Rhynchonella</i> <i>globata.</i> <i>subtetraedra.</i> <i>Terebratula decipiens</i> ? † <i>Terebratula</i> <i>Acanthothyris</i> <i>sphæroidalis.</i> <i>spinosa.</i> <i>Terebratula</i> , an ovoid feebly bi- plicate form of the <i>punctata-</i> <i>Rhynchonella</i> group. <i>plicatella.</i> <i>Terebratula</i> aff. <i>Phillipsi</i> , but shorter and less plicate. <i>Aulacothyris carinata.</i> <i>Rhynchonella</i> aff. <i>parvula.</i>
GARANTIANÆ.	<i>Parkinsonia garantiana</i> , d'Orb. <i>Sphæroceras</i> aff. <i>Brongniarti</i> , Sow.  <i>Belemnites.</i>	† <i>Rhynchonella subtetraedra.</i> <i>Acanthothyris spinosa.</i> <i>Rhynchonella</i> aff. <i>angulata</i> , Sow. <i>Terebratula</i> between <i>globata</i> and <i>Hollandæ.</i> <i>Zeilleria</i> , sp. cf. Davidson, 'Bra- chiopoda,' Suppl. pl. xxiv. figs. 16 & 17; also cf. <i>Hughesi.</i>
SAUZEI.	† <i>Stephanoceras contractum</i> , J. de C. Sowerby. <i>Stephanoceras Sauzei</i> , d'Orb. † " <i>Braikenridgii</i> , J. de C. Sowerby. <i>Stephanoceras</i> aff. <i>Bayleanum</i> , Oppel. <i>Stephanoceras</i> , a crassicostate form. † <i>Sonninia corrugata.</i> " <i>mesacanthus</i> (Waa- gen). <i>Oppelia præradiata</i> , Douvillé. ' <i>Cadomoceras</i> , ' sp. † <i>Sonninia Sowerbyi</i> (Miller). <i>Belemnites aalensis</i> , Voltz. " <i>ellipticus</i> , Miller. <i>Nautilus ornatus</i> , Foord and Crick.	<i>Terebratula</i> aff. <i>Hartmanni.</i> <i>Acanthothyris paucispina.</i> A somewhat flattened <i>Terebra-</i> <i>tula</i> aff. <i>sphæroidalis.</i> † <i>Rhynchonella dundriensis</i> , S. Buckm.
WITCHELLIÆ.	† <i>Witchellia læviuscula.</i> " aff. <i>Sutneri.</i> <i>Sphæroceras Brocchi</i> (Sowerby).	

TABLE V. (continued).

HEMERAÆ.	CEPHALOPODA.	BRACHIOPODA.
SONNINIAÆ.	<p>(*) <i>Lissoceras</i>, sp. ? ' <i>Am. subradiatus</i>, ' S. P. Woodward, non Sowerby.</p> <p>(*) ' <i>Sphæroceras</i>, ' the small form called <i>Brocchii</i> by Sowerby.</p> <p>† <i>Sonninia Browni</i>, Sowerby.</p> <p>" <i>fissilobata</i>.</p> <p>" <i>Stephani</i> (S. Buckm.).</p> <p>" <i>ovalis</i>.</p> <p>" aff. <i>gracililobata</i> (Quenst.).</p> <p><i>Sonninia Zuricheri</i>.</p> <p><i>Strigoceras compressum</i> (Etheridge).</p>	<p>? <i>Terebratula</i> aff. <i>Uptoni</i>, S. Buckm. [coll. Mr. J. W. D. Marshall.]</p> <p><i>Terebratula crickleyensis</i>, S. Buckm. [coll. Mr. J. W. Tutchener.]</p>
DISCITEÆ.	<p><i>Lissoceras Etheridgii</i>, S. Buckman.</p> <p><i>Hyperlioceras</i> aff. <i>discites</i>.</p> <p>" aff. <i>Walkeri</i>.</p> <p><i>Lioceras intermedium</i>.</p> <p><i>Belemnites Blainvillei</i>.</p>	<p><i>Terebratula cortonensis</i>, S. Buckm.</p> <p><i>Terebratula Eudesiana</i>, S. Buckm.</p> <p><i>Rhynchonella Forbesi</i>, Dav.</p> <p>('immediately above stone, with <i>Terebratula Eudesi</i>, E. Wilson).</p>
CONCAVI.	<p><i>Lioceras concavum</i>.</p> <p>" v-scriptum.</p>	<p>† <i>Terebratula Eudesi</i>, Oppel.</p> <p>† " <i>perovalis</i>, Dav.</p> <p>" <i>cortonensis</i>.</p>
BRADFORDENSIS & MURCHISONÆ.	<p><i>Lioceras</i> cf. <i>bradfordense</i>.</p> <p><i>Ludwigia obtusa</i> (Quenstedt).</p>	<p><i>Terebratula shirbuirniensis</i>.</p> <p>? " <i>Leesi</i>.</p> <p>† " <i>Etheridgii</i>, Dav.</p> <p>† <i>Zeilleria anglica</i>, Oppel.</p> <p><i>Rhynchonella</i> aff. <i>Stephensi</i>, Dav.</p>
OPALINI & AALENSIS.	<p><i>Grammoceras subserridens</i>, Branco.</p> <p><i>Grammoceras</i> aff. <i>lotharingicum</i> (Branco).</p> <p><i>Grammoceras aalense</i> (Zieten).</p> <p>" aff. <i>aalense</i> (Zieten).</p> <p><i>Grammoceras leurum</i>, S. Buckman, cf. 'Monogr. Inf. Ool. Ammonites,' Pal. Soc. vol. for 1889, issued 1890, pl. xxxiii. fig 8.</p> <p><i>Grammoceras subcomptum</i>.</p>	<p><i>Rhynchonella</i>, sp., like a dwarf form of <i>cynoprosopa</i>, S. Buckm.</p> <p><i>Rhynchonella Stephensi</i>.</p> <p><i>Terebratula</i> aff. <i>infra-oolithica</i>, E. Desl.</p> <p><i>Aulacothyris Blakei</i>.</p>
DUMORTIERIÆ.	<p><i>Catullocceras Dumortieri</i> (Thiollière).</p> <p><i>Dumortieria</i> aff. <i>radians</i> (Reinecke).</p> <p><i>Dumortieria</i> aff. <i>prisca</i>, S. Buckman.</p> <p><i>Hudlestonia</i> aff. <i>serridens</i>.</p> <p><i>Hammatoceras</i>, sp., in the early part of this hemera.</p>	<p>? <i>Zeilleria</i> aff. <i>Lycetti</i>.</p> <p><i>Rhynchonella Moorei</i>, Dav.</p>

TABLE V. (continued).

HEMERÆ.	CEPHALOPODA.	BRACHIOPODA.
DISPANSI.	? <i>Grammoceras Struckmanni.</i> " <i>doerntense,</i> Denckm.	<i>Rhynchonella</i> aff. <i>jurensis</i> , Dav., non Quenst.
STRIATULI.	<i>Grammoceras striatulum.</i> " <i>toarcense.</i> " aff. <i>Sæmanni.</i> <i>Haugia</i> aff. <i>Eseri.</i> Canaliculate belemnites. Cylindrical belemnites.	<i>Rhynchonella</i> aff. <i>jurensis</i> , Dav., non Quenst. <sup>1</sup>
VARIABILIS.	<i>Haugia</i> aff. <i>jugosa.</i> <i>Haugia</i> , n. sp., aff. <i>illustris,</i> Denckm. Form of the <i>Lillia Lilli</i> type.	<i>Zeilleria</i> between <i>Lycetti</i> and <i>anglica.</i> <i>Rhynchonella</i> aff. <i>jurensis</i> , Dav., non Quenst., but a form different from those mentioned above.
BIFRONTIS.	<i>Dactylioceras</i> aff. <i>Desplacei.</i> " cf. <i>commune.</i> " aff. <i>subarmatum,</i> Dumortier. <i>Hildoceras bifrons.</i>	
FALCIFERI.	<i>Dactylioceras</i> aff. <i>commune.</i> " aff. <i>annulatum.</i> <i>Harpoceras falciferum</i> (Sow.). " <i>exaratum.</i> " aff. <i>Strangwaysi</i> (Sow.). " <i>capellinum</i> (Quenst.). <i>Pseudolioceras</i> ?, sp. <i>Hildoceras Levisoni.</i>	
SPINATI & MARGARITATI.	<i>Pleuroceras</i> aff. <i>nudum</i> (Quenst.). <i>Amaltheus margaritatus.</i>	<i>Terebratulula punctata.</i> <i>Rhynchonella tetraedra.</i> " <i>northamptonensis.</i> <i>Zeilleria indentata</i> ?, fragment. <i>Rhynchonella</i> aff. <i>subdecussata,</i> Zittel, 'Geol. Beobachtungen aus den Central Apenninen,' pl. xiv. (2) fig. 12; Geogn. Pal. Beitr. vol. ii. pt. ii. Munich, 1869.

<sup>1</sup> Said by Mr. J. F. Walker to be near his *Rhynchonella bothenhamptonensis*, mentioned but not figured, Geol. Mag. 1892, p. 442.

*Palæontological Notes upon certain Species mentioned in the foregoing Table.* [S. S. BUCKMAN.]

*Stephanoceras contractum*.—The type came from Dundry; whether the name *Sauzei* may also be used for a coarser form than Sowerby's is a matter for future determination. It seems probable; but the two forms are closely allied. They are not true *Stephanocerata*.

*Sphæroceras Brocchi*.—The larger of the specimens figured by Sowerby must be taken as the type, and it is from Sherborne (Dorset). The smaller is a different species, much more umbilicate, and is from Dundry. It is a common form, but it has no name.

*Strigoceras compressum* (Etheridge).—In the communication incorporated in Wright's paper, Etheridge quotes a species as '*Ammonites Truelli*, var. *compressus*.'<sup>1</sup> This may be translated as an ammonite with characters like *Truelli*, but more compressed. The description applies to more than one species of Dundry ammonite, but probably the largest of the forms of *Truelli*-like ammonites may merit the name best.

*Oppelia subradiata* (J. de C. Sowerby).—The author says<sup>2</sup>:—'Found . . . on the road from Bath to Bristol; it has been broken out of a mass of Ironshot Oolite.' The species now usually called by this name lived during the *niortensis* hemera, but, as there are no strata of that date at Dundry Hill, there must be some mistake in the present identifications. The type presumably came from the Ironshot bed of the *Sauzei* hemera, or from the softer stratum just below; but I am unable to say anything concerning it. As *subradiatus* is the type of the genus *Oppelia*, its correct identification is a matter of great importance, and the result may alter entirely the present application of the generic term *Oppelia*. As Sowerby's type is in the British Museum, a further comparison of the Dundry *Oppelia* therewith will be the solution of the difficulty.

*Lissoceras*? '*subradiatum*' (S. P. Woodward), non J. de C. Sowerby.—This is not the same species as the *Ammonites subradiatus* of Sowerby, and in fact S. P. Woodward himself notes points of difference.<sup>3</sup> It may not be the same genus, for it possibly is a parent of *oolithicus*, d'Orbigny, the type of *Lissoceras*, which Sowerby's *subradiatus* certainly cannot be.

H. B. Woodward states that the specimen came from the *Parkinsoni*-zone,<sup>4</sup> but this must be an oversight. The probable horizon is given in Table V. It certainly did not occur above the Ironshot, but the exact identification of the fossil, for there are several allied forms, is not possible from the figure given by S. P. Woodward. This also is a matter for comparison with the actual specimen in the British Museum.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 24.

<sup>2</sup> 'Min. Conch.' vol. v. p. 23.

<sup>3</sup> 'The Geologist,' vol. iii. no. 33, p. 328.

<sup>4</sup> Mem. Geol. Surv., 'The Lower Oolitic Rocks of England,' in 'Jurassic Rocks of Britain,' vol. iv. (1894) p. 99.

*Pleuroceras* aff. *nudum* (Quenstedt).—The species is between *Pleuroceras vittatum*, Phillips, 'Geol. Yorkshire,' pl. xiii. fig. 1, and *Pleur. nudum*, Quenstedt, 'Der Jura,' pl. xxi. fig. 3. It is, however, without the tubercules shown in the first species, particularly the inner row, while it is much more distantly costate than the other, and presumably a more robust shell than Quenstedt had to figure.

*Rhynchonella dundriensis*, S. Buckman.—The type is in the Bristol Museum, and no other specimen has been found at Dundry. The appearance of the Dorset specimens suggested that the species lived in the *Humphriesiani* hemera, the given locality, Bradford Abbas, being often applied somewhat indefinitely by the working fossil-collectors. However, there are no strata of the *Humphriesiani* hemera at Dundry; and so the date now assigned is more likely to be correct, both for Dundry and Dorset.

*Terebratula* aff. *infra-oolithica*, E. Deslongchamps.—The specimens mentioned by this name agree closely with examples of *T. infra-oolithica* from Condé-sur-Sarthe, kindly given to me by Prof. Bigot. They differ in the smaller size of beak and foramen, and a slightly more pronounced carination of the perforate valve. Both the Dundry and French forms differ appreciably from the Dorset specimens which have hitherto been identified as *T. infra-oolithica*.

*Zeilleria anglica* (Oppel).—In his 'Juraformation,' p. 425, § 53, No. 216, Oppel gave this name to a shell which he collected at Burton Bradstock with *Amm. opalinus, torulosus*, and *subinsignis*. He says the specimens agree remarkably ('stimmen auffallend') with the species figured by Davidson, Mon. Brach. (Pal. Soc.) vol. i. Append. tab. A, figs. 10–13, from the Inferior Oolite of Dundry. There are, however, certain differences to be noted in these shells. The Burton-Bradstock specimens, which are from a lower horizon, are certainly more lenticular, have more convex valves, a more prominent umbo, and a more distinctly separated beak, with a larger foramen. This Burton Bradstock shell agrees better with what Deslongchamps has figured as *Terebratula* (*Waldheimia*) *Lycetti*, Pal. Franç., Brachiopodes, pl. xlvii. figs. 4–10; but this is not the *Lycetti* of Davidson, which is a more elongate shell. As Oppel did not figure his shell, but gave a reference to Davidson, and as Davidson's shell has been figured by the name *anglica*, and known by that appellation so long, it is desirable to leave it untouched; but the Burton Bradstock shell may be distinguished as *Zeilleria Oppeli*.

*Zeilleria Oppeli*, S. Buckman.

1856. *Terebratula anglica*, Oppel, pars, 'Juraformation,' p. 425.

1862. *Terebratula* (*Waldheimia*) *Lycetti*, Deslong. (non Dav.) 'Brachiopodes Terr. Jurass.' pl. xlvii. figs. 7 & 9.

*Description*.—A subpentagonal shell with somewhat gibbous valves uniting in an almost sharp margin. Beak fairly incurved, distinct, foramen rather large, beak-ridges and area fairly pronounced.



TABLE V. A.—THE FAUNA, SEQUENCE AT DUNDRY. [E. WILSON.]

Note.—Those marked † are type-forms named from Dundry specimens. Those figured from Dundry, but not specific types, are marked (\*).

HEMERA.	GASTEROPODA.	LAMELLIBRANCHIATA.	ECHINODERMATA, CORALS, ETC.
<i>Pleurotomaria Palemon</i> (d'Orb.).	<i>Trigonia costata</i> (Sow.). <i>Lithodomus inclusus</i> , Phil. <i>Ostrea gregaria</i> , Sow. <i>Lama</i> , sp.	? <i>Pentactinus Milleri</i> , Austen. <i>Magnoia Forbei</i> , Wright. <i>Hemicidaris granulosa</i> , Wright. <i>Cidaris Fowleri</i> , Wright. " <i>Bouchardi</i> , Wright. ? <i>Holactypus hemisphericus</i> , Ag. <i>Collyrites ringens</i> , Ag.	
<i>Pleurotomaria actinophala</i> , Desl. " <i>monticulus</i> , Desl. " <i>ornata</i> , Münster. " <i>oxytera</i> , Hudleston. † <i>Ambertegia ornata</i> , Sow. † <i>Alaria dundriensis</i> , Tawney. † <i>Natica dundriensis</i> , Tawney.	<i>Opis similis</i> , Sow. ? <i>Myconocha crassa</i> , Sow. ? <i>Cypripicardia bathonica</i> , d'Orb. ? <i>Pecten barbatus</i> , Sow. <i>Unicardium gibbosum</i> , M. & L.	<i>Tima Eberhardi</i> , Wright	

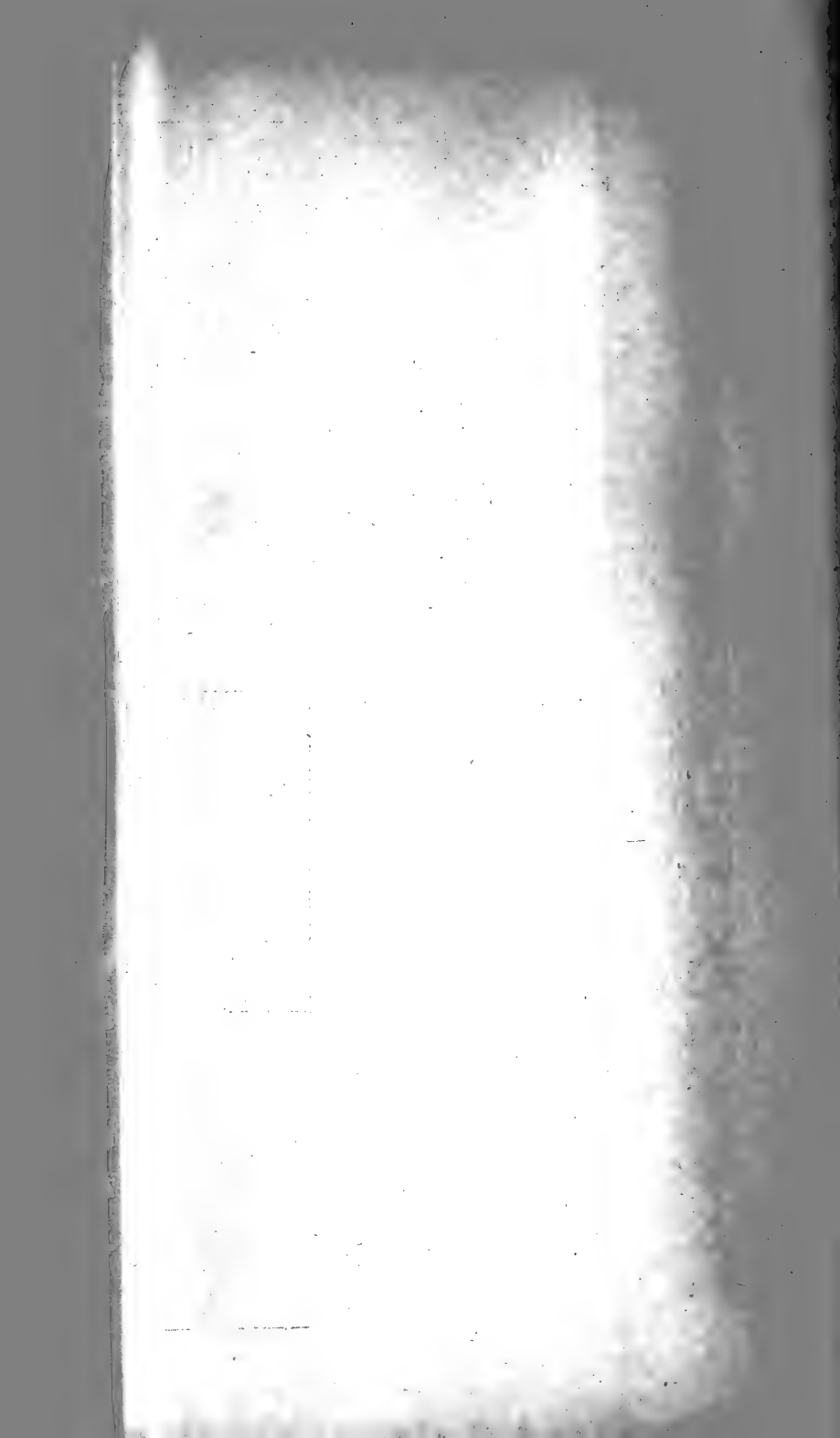


TABLE VA.—THE FAUNAL SEQUENCE AT DUNDRY. [E. WILSON.]

Note.—Those marked † are type-forms named from Dundry specimens. Those figured from Dundry, but not specific types are marked (\*).

HERM.F.	GASTROPODA.	LAMELLIBRANCHIATA.	ECHINODERMATA, CORALS, ETC.
Post-GARANTIANÆ (Cornilite and Freshstone).	<i>Pleurotomaria Paterson</i> (d'Orb.).	<i>Trypania costata</i> (Sow). <i>Lichodinus tinctus</i> , Phil. <i>Ostrea gregaria</i> , Sow. <i>Lima</i> , sp.	† <i>Pentactinus Milleri</i> , Ansem. <i>Maqueta Poppei</i> , Wright. <i>Hemitarsus granulosa</i> , Wright. <i>Cidaris</i> <i>Pouletii</i> , Wright. ? <i>Holætylus hemisphericus</i> , Ag. <i>Callipterus ringens</i> , Ag. <i>Hydrolytus ovalis</i> , Wright. <i>Stomochinus intermedius</i> , Ag. " <i>bipinnularis</i> , Lam. <i>Isactrea Richardsi</i> , E. & H. " <i>lonsdalei</i> , E. & H. " <i>tenistrida</i> , McCoy. <i>Thamnatræa Depratensis</i> , Mich. " <i>leguani</i> , E. & H. " <i>M. Edw.</i> <i>Lathincorda Pithouiti</i> , E. & H. <i>Montivallia lens</i> , E. & H. <i>Glypta rostrata</i> ? <i>Serphobates</i> , sp. ?
GARANTIANÆ.	<i>Pleurotomaria Paterson</i> , d'Orb. <i>Pseudomelania</i> aff. <i>corretata</i> , Desl. <i>Athyris Labaudi</i> , d'Arch. " <i>obliquis</i> , Hudleston. <i>Trochus biarmatus</i> , Munst. <i>Actæa bujocensis</i> , d'Orb. <i>Trochus dimidiatus</i> , Sow. <i>Amberleya</i> aff. <i>ornata</i> , Sow.	<i>Lima Lycei</i> , Lamb. " <i>semitruncata</i> , Goldfuss. <i>Astarte</i> aff. <i>obliqua</i> , Desl. " <i>Monsei</i> , S. Buckn. <i>Limetella gibbosa</i> , Sow. <i>Goniatia ovalis</i> , Quenstedt. <i>Ctenostreon pectiniforme</i> , Sow. <i>Trypania costata</i> , Sow. <i>Opis angulatus</i> , J. Buckman. " <i>humilatus</i> , Sow. † <i>Trypania</i> cf. <i>Moretoni</i> and <i>nalfordi</i> . " <i>impuncta</i> , Lycei.	<i>Montivallia lens</i> , E. & H.
SATZEL.	<i>Pleurotomaria elongata</i> , Sow. " <i>phlogaspire</i> , d'Orb. " <i>ornata</i> , var. <i>Munsteriana</i> , Desl. " <i>opuncta</i> , Sow. " <i>granulata</i> , Sow. " <i>distinquenda</i> , Tawney. " <i>faciata</i> , Sow. " <i>sulcata</i> , Sow. " <i>subreticulata</i> , d'Orb. " <i>Polius</i> , Desl. " <i>abruptata</i> , Sow. " <i>subarmatus</i> , Hudlest. " <i>parvistrata</i> , d'Orb. " <i>Trochus Zeis</i> , d'Orb. " <i>Diophrus levigatus</i> , Sow. <i>Pseudomelania lineata</i> , Sow. <i>Cerithium subacutiforme</i> , d'Orb. † <i>Spilargus trinitatis</i> , Tawney. † <i>Stergiprotus dundreensis</i> , Tawney.	<i>Gonionya angulifera</i> , Sow. <i>Astarte multicostrata</i> , S. Buckn. <i>Mytilus Juvvosi</i> , Brong. <i>Goniatia Hartmanni</i> , Münster. <i>Platodonta sparsata</i> , Whitborne. " <i>cf. filicula</i> , Sow. † <i>Harpax Tawneyi</i> , Whitborne. " <i>humilatus</i> , Sow. <i>Cucullæa oblonga</i> , Sow. " <i>elongata</i> , Phil. ? " <i>concellata</i> , Phil. ? <i>Ostrea febelloides</i> Lam. = <i>O. Marshii</i> , Sow. " <i>explorata</i> , Münster. <i>Lima alticosta</i> , Ch. & Dew. <i>Hemitars obliqua</i> , Phillips. <i>Ctenostreon pectiniforme</i> , Sow. <i>Isactræa gibbosa</i> , Munst.	<i>Serpula granulis</i> , Münster. <i>Diplocladia</i> , sp. (spine).
WICHELLE.	<i>Pleurotomaria actinophala</i> , Desl. " <i>montivallia</i> , Desl. " <i>ornata</i> , Münster. " <i>opuncta</i> , Hudleston. † <i>Amberleya ornata</i> , Sow. † <i>Actæa dundreensis</i> , Tawney. † <i>Natica dundreensis</i> , Tawney.	<i>Opis similis</i> , Sow. ? <i>Myconcha crassa</i> , Sow. ? <i>Cypripentia bathonica</i> , d'Orb. <i>Utracordium gibbosum</i> , M. & L.	
SOKKINÆ.		<i>Lima Elberfeldi</i> , Wright. <i>Mytilus Juvvosi</i> , Brong. <i>Ctenostreon pectiniforme</i> , Sow. <i>Trypania striata</i> , Sow. <i>Gressya abneta</i> , Phill. <i>Platodonta Marshi</i> , Sow.	
DISCITE.		<i>Astarte elegans</i> , Sow. " <i>excavata</i> , Sow. <i>Lima Elberfeldi</i> , Wright. <i>Myconcha crassa</i> , Sow. " <i>implana</i> , Whitb.	
CONCAY.		<i>Modiola Souerbyana</i> , d'Orb. ? <i>Myconcha crassa</i> , Sow. ? <i>Ceryoncha bujocana</i> , d'Orb.	<i>Serpula pilositis</i> , Münster attached to <i>Terebratulæ cottenensis</i> and <i>T. Endesi</i> .
BRADPODENSIS & MURCHISONÆ.	<i>Pleurotomaria</i> † <i>Mopsis</i> , d'Orb. " <i>Stoddarti</i> , Tawney. " <i>dundreensis</i> , Tawney. " <i>niortensis</i> , d'Orb. " <i>cf. subdecorata</i> , Mun. ? " <i>angulata</i> , d'Orb. " <i>punctata</i> , Sow. † <i>Cyprus nodosus</i> , Sow. † " <i>pyramidalis</i> , Tawney. † " <i>Leachi</i> , Sow. " <i>Calisto</i> , d'Orb. " <i>Amberleya (Turbo) Stoddarti</i> , Tawn.	<i>Trypania striata</i> , Sow. <i>Mytilus</i> aff. <i>Juvvosi</i> , Brong. ? <i>Opis triquatus</i> , Sow. ? <i>Cypripentia cordiformis</i> , Desl.	
OPALINI & ADELPHIS.		<i>Lima</i> aff. <i>Elberfeldi</i> , Wright. <i>Platodonta filicula</i> , Sow.	
DUNDRENIÆ to FALCIBERI.		No species have been recorded.	
SPINATI & MARGARITÆ.		<i>Pseudopecten equinatus</i> , Sow. <i>Gryphæa cymbium</i> , Lam. ? or <i>Ostrea giganta</i> . <i>Astarte</i> .	

† There is some doubt as to the correct date of these Dundry *Pleurotomaria*, the character of the matrix of specimens in the Bristol Museum, in this as in many other cases, being all the evidence available.



*Differences from the shell now called Zeilleria anglica.*—The valves are much more convex in every way, especially towards the posterior portion of the shell. The fossil therefore appears thicker, with a more pronounced anterior slope than *Z. anglica*. The beak portion of the perforate valve appears more pronounced and curved; the beak too is itself larger, with more pronounced area and ridges, and a decidedly larger foramen. This matter of the beak is a very noticeable character, because the beak of *Z. anglica* is small and delicate to a marked degree.

*Time of Existence.* In the hemera *scissi*, or in that of *opalinus*; but *Zeilleria anglica* lived during the hemera *Murchisonæ*.

*Locality.* Burton Bradstock, Dorset.

*Remarks.* Deslongchamps, *op. cit.* pl. xlvii. fig. 7, shows the shape as well as the usual size: in fact, the specimens are but little larger than this. On the other hand, *Z. anglica* attains to twice this size. Deslongchamps' fig. 7 also shows the character of the beak, and may in this matter be suitably compared with Davidson's pl. A, figs. 10–13. Deslongchamps' fig. 7 may be taken as representing *Zeilleria Oppeli* with considerable fidelity.

The faunal sequence at Dundry shown by other classes of fossils is given in Table V A., facing p. 702.

The following is a list of the species described by Whidborne<sup>1</sup> as from the Inferior Oolite of Dundry, with the horizons, when they are stated. It will be useful, as a supplement to the lists we have given, to show what palæontological results have been yielded by Dundry. We would, of course, remark that his *Humphriesianum*-zone is evidently of somewhat wide interpretation; but it may be considered to be principally 'the Ironshot Oolite,' with certainly beds above and below—in all probability strata deposited from the hemera *discite* until that of *Garantianæ*.

#### DUNDRY MOLLUSCA DESCRIBED BY WHIDBORNE.

- Arca culmotecta*, Whidborne.
- \* *Astarte suffluta*, Römer.
- † *Cardium dundriense*, Whidb.
- † " *pulsatum*, Whidb.
- † *Cypricardia filoperta*, Whidb.
- † *Gervillia gladiolus*, Whidb.
- " *intermedia*, Whidb.
- † *Gryphæa abrupta*, Whidb.
- " *cymbium*,<sup>2</sup> Lam. 'Humphriesianum-zone.'
- † " *Sollasi*, Whidb.
- † *Harpax Tawneyi*, Whidb. 'Ironshot Oolite.'
- Hinnites tenuistriatus*, Münster. 'Top of Humphriesianum-zone.'
- Leda lacryma*, Sowerby. 'Base of Inferior Oolite.'

\* Figured specimens.

† Type-specimens.

<sup>1</sup> 'Notes on some Fossils, chiefly Mollusca, from the Inferior Oolite,' Quart. Journ. Geol. Soc. vol. xxxix. (1883) p. 487.

<sup>2</sup> He notes that this is truly a Middle Lias fossil. This is evidently a case of confusion of the Marlstone with the Ironshot Oolite.

DUNDRY MOLLUSCA (*continued*).

- Lima alticosta*, Chap. & Dew. 'Upper part of *Humphriesianum*-zone.'  
 „ *aequilatera*, Buv.  
 „ *educta*, Whidb.  
 „ *plebeia*, Chap. & Dew. 'Ironshot Oolite.'  
 † „ *poetica*, Whidb.  
 „ *rigida*, Sow.  
 „ *semicircularis*, Goldf. '*Humphriesianum*-zone.'  
*Lucina burtonensis*, Lycett.  
 † *Macrodon rapidus*, Whidb. '*Humphriesianum*-zone.'  
 † *Myacites subsidens*, Whidb.  
 † *Myoconcha unguis*, Whidb.  
 „ *implana*, Whidb.  
 † *Mytilus striatissimus*, Whidb.  
 † *Nucula nuciformis*, Whidb.  
*Ostrea explanata*, Goldf. '*Humphriesianum*-zone.'  
 „ *palmetta*, Sow., var. *montiformis*, Whidb.  
*Pecten aratus*, Waagen. '*Humphriesianum*-zone.'  
 ? „ *cornutus*, Quenst.  
 „ *fenestralis*, Whidb.  
 „ *laeviradiatus*, Waag.  
 † „ *spinicostatus*, Etheridge. 'Beds above the Ironshot Oolite  
 belonging to the higher part of the *Humphriesianum*-zone.'  
 † *Pholadomya callæa*, Whidb. 'Ironshot beds.'  
 † „ *fortis*, Whidb.  
 † „ *spatiosa*, Whidb. 'Ironshot beds of *Humphriesianum*-zone.'  
 † *Pinna dundriensis*, Whidb.  
 † *Placuna sagittalis*, Whidb.  
 † *Plicatula Sollasi*, Whidb. '*Humphriesianum*-zone, upper part.'  
*Placunopsis semistriata*, Bean.  
 \* *Rhabdocidaris Thurmanni*, var. *repens*, Whidb. 'Upper beds of  
*Humphriesianum*-zone.'  
 † *Sphæra fimbriata*, Whidb.  
*Spondylus nidulans*, E. Desl. '*Humphriesianum*-zone.'  
 † *Terebratula Tawneyi*, Whidb. 'Upper beds of *Humphriesianum*-zone.'  
 † *Thracia leguminosa*, Whidb.

\* Figured specimens.

† Type-specimens.

## VII. THE CORRELATION OF THE DUNDRY STRATA WITH THE ROCKS OF THE COTTESWOLD AND DORSET-SOMERSET AREAS.

In four parallel columns in Table VI. the following information is given:—

- I. The time divisions—the sequence of hemeræ.
- II. The sequence of deposits in the Cotteswolds which have been laid down during these hemeræ.
- III. The sequence of Dundry deposits.
- IV. The sequence of strata found in the Dorset-Somerset area, south of the Mendips.

Thus in these four parallel columns the contemporaneous deposits of each district may be noted side by side. Our remarks upon the comparative development of the deposits in the different areas will be found incorporated in the following pages.

TABLE VI.—CORRELATION OF THE DUNDRY STRATA WITH THE ROCKS OF THE COTTESWOLD AND DORSET-SOMERSET AREAS.

HEMER.	COTTESWOLDS.	DUINDRY.	DORSET-SOMERSET.
ZIGZAG <sup>1</sup> .....	Limestones above the <i>Clypeus</i> -grit.	(?) The strata at Barns Batch. The Coralline Beds.	The zigzag-beds of Broad Windsor, Dorset.
TEUFELII <sup>1</sup> .....	The <i>Clypeus</i> -grit.	The Dundry Freestone.	The fossil-bed of Halfway House with <i>Tynellii</i> and <i>dorsetensis</i> .
CHARACTIANE .....	The Upper <i>Trygonia</i> -grit.	The Conglomerate-bed of Maes Knoll = the thin bed below the Freestone at other places.	The Freestones of Sherborne.
NIOBIENSIS.....	NO STRATA.	NO STRATA.	The upper part of the roadstone of Osborne = Bifurcaten Schichten of Württemberg.
HUMPHRIESIANI .....	NO STRATA.	NO STRATA.	The lower part of the roadstone of Osborne = Coronaten Schichten of Württemberg.
SAUZEI.....	Perhaps the <i>Phillipsiana</i> -beds of Clevea Hill	The Ironshot Oolite of Dundry.	The upper part of the Sandford Lane

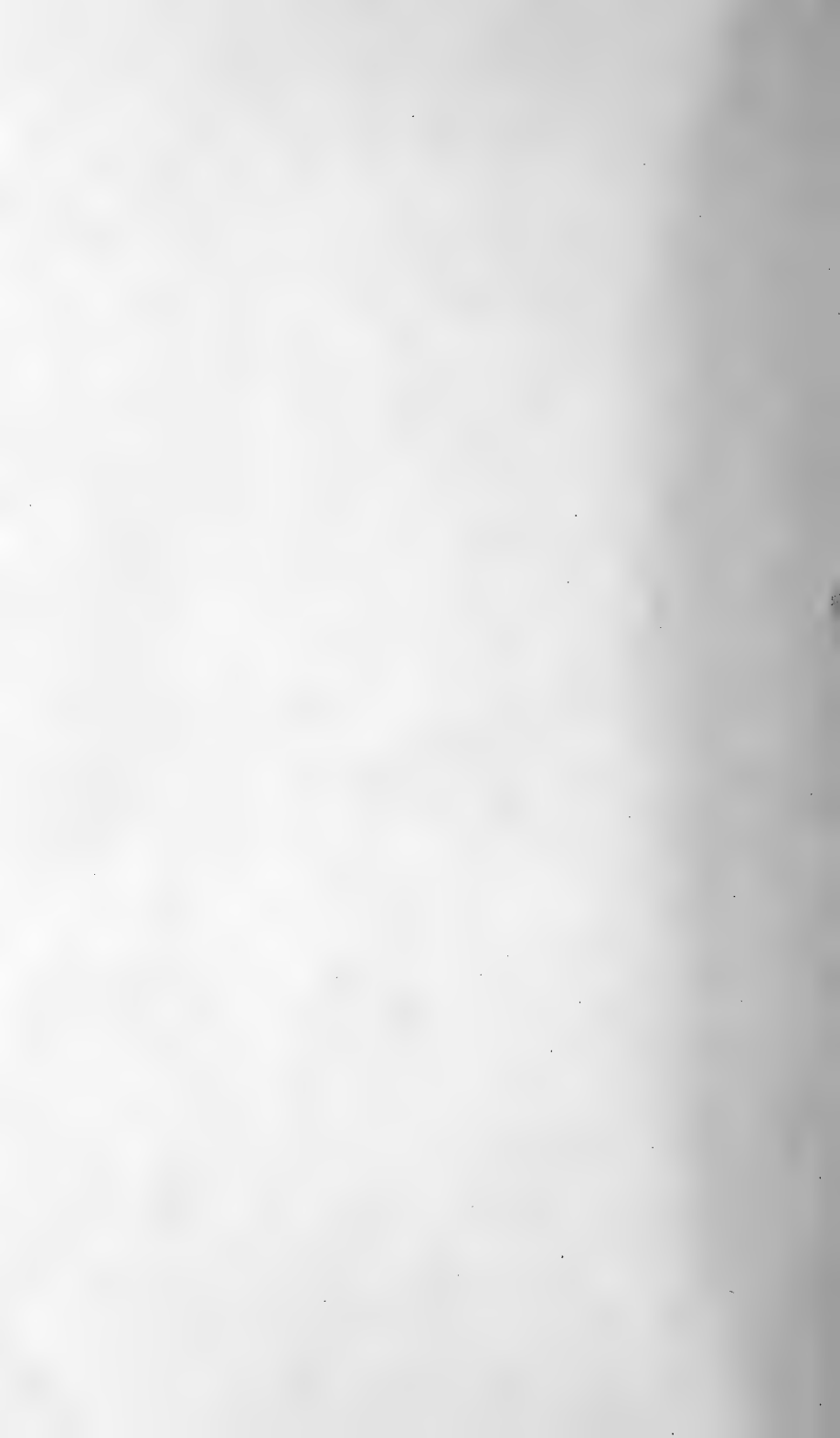




TABLE VA.—THE FAUNAL SEQUENCE AT DUNDY. [E. WILSON.]

Note.—Those marked † are type-forms named from Dundry specimens. Those figured from Dundry, but not specific types, are marked (\*).

HEWERÆ.	GASTROPODA.	LAMELLIBRANCHIATA.	ECHINODERMATA, CORALS, ETC.
	<i>Pleurotomaria Palemon</i> (d'Orb.).	<i>Trigonia costata</i> (Sow.), <i>Lithodomus inclusus</i> , Phil. <i>Ostrea gregaria</i> , Sow. <i>Lima</i> , sp.	? <i>Pentactinus Milleri</i> , Abston. <i>Magnolia Forbesi</i> , Wright. <i>Hemicidaris granulosa</i> , Wright. <i>Cidaris Fowleri</i> , Wright. " <i>Bouchardi</i> , Wright. ? <i>Holcelypus hemisphericus</i> , Ag. <i>Collyrites tingens</i> , Ag. <i>Hyporhynchus ovatus</i> , Wright. <i>Stomechinus intermedius</i> , Ag. " <i>bipartularis</i> , Lam. <i>Isastræa Richardsoni</i> , E. & H. " <i>Lonsdalei</i> , E. & H. " <i>tenuistriata</i> , McCoy. " <i>explanata</i> , McCoy. <i>Thamastrea Defranciæna</i> , Mich. " <i>Terquemii</i> , E. & H., M. Edw. <i>Laimanatra Flemingii</i> , E. & H. <i>Montlivaltia lens</i> , E. & H. <i>Glypheca rostrata</i> ? <i>Strophodus</i> , sp.? <sup>1</sup>
POST-GARANTIANÆ (Coralline and Freestone).	<i>Pleurotomaria Palemon</i> , d'Orb. <i>Pseudomelania</i> aff. <i>coarctata</i> , Desl. <i>Ataphrus Labardei</i> , d'Arch. " <i>obortus</i> , Huddleston. <i>Trochus biarmatus</i> , Münster. <i>Natica bajocensis</i> , d'Orb. <i>Trochus dimidiatus</i> , Sow. <i>Amberleya</i> aff. <i>ornata</i> , Sow.	<i>Lima Lyceetti</i> , Laube. " <i>semicircularis</i> , Goldfuss. <i>Astarte</i> aff. <i>obliqua</i> , Desh. " <i>Manseli</i> , S. Buckm. <i>Limnula gibbosa</i> , Sow. <i>Gouldia ovalis</i> , Quenstedt. <i>Ctenostreon pectiniforme</i> , Sow. <i>Trigonia costata</i> , Sow. <i>Opis angulatus</i> , J. Buckman. " <i>lunulatus</i> , Sow. † <i>Trigonia</i> cf. <i>Moretoni</i> and <i>Walfordi</i> , " <i>duplicata</i> , Lycect.	<i>Montlivaltia lens</i> , E. & H.
GARANTIANÆ.	<i>Pleurotomaria elongata</i> , Sow. " <i>pligospira</i> , d'Orb. " <i>armata</i> , var. <i>Munsteriana</i> , Desl. " <i>ornata</i> , Sow. " <i>granulata</i> , Sow. " <i>distinctuenda</i> , Tawney " <i>fasciata</i> , Sow. " <i>sulcata</i> , Sow. " <i>subreticulata</i> , d'Orb. " <i>Proleus</i> , Desl. " <i>abbreuitata</i> , Sow. " <i>subaraneosa</i> , Huddlest. " <i>punctistriata</i> , d'Orb. " <i>Trochus Zetes</i> , d'Orb. " <i>Ataphrus levigatus</i> , Sow. <i>Pseudomelania lineata</i> , Sow. <i>Cerithium subscalariforme</i> , d'Orb. † <i>Spinigera trinitatis</i> , Tawney. † <i>Strophapollus dundrensis</i> , Tawney.	<i>Goniomya angulifera</i> , Sow. <i>Astarte multicastrata</i> , S. Buckm. <i>Myacites Jurassi</i> , Brong. <i>Gervillia Hartmanni</i> , Münster. <i>Pholadomya spatiosa</i> , Whitborne. " <i>deencostata</i> , Römer. " cf. <i>fulvicula</i> , Sow. + <i>Harpax Tawneyi</i> , Whitborne. <i>Opis lunulatus</i> , Sow. <i>Cucullæa oblonga</i> , Sow. " <i>elongata</i> , Sow. " <i>cancelata</i> , Phill. <i>Ostrea flabelloides</i> , Lam. = <i>O. Marshii</i> , Sow. " <i>explanata</i> , Münster. <i>Lima alticosta</i> , Ch. & Dew. <i>Hinnites abjectus</i> , Phillips. <i>Ctenostreon pectiniforme</i> , Sow. <i>Isocrardia gibbosa</i> , Münster.	<i>Serpula grandis</i> , Münster. <i>Diplœiæaris</i> , sp. (spine).
SAUZEI.	<i>Pleurotomaria actinophala</i> , Desl. " <i>monticulius</i> , Desl. " <i>armata</i> , Münster. " <i>argyrea</i> , Huddleston. + <i>Amberleya ornata</i> , Sow. + <i>Alaria dundrensis</i> , Tawney. + <i>Natica dundrensis</i> , Tawney.	<i>Opis similis</i> , Sow. ? <i>Myoconcha crassa</i> , Sow. ? <i>Cypriocardia bathonica</i> , d'Orb. <i>Pecten barbatus</i> , Sow. <i>Unicartium gibbosum</i> , M. & L.	
WITCHELLIÆ.	<i>Pleurotomaria actinophala</i> , Desl. " <i>monticulius</i> , Desl. " <i>armata</i> , Münster. " <i>argyrea</i> , Huddleston. + <i>Amberleya ornata</i> , Sow. + <i>Alaria dundrensis</i> , Tawney. + <i>Natica dundrensis</i> , Tawney.	<i>Lima Etheridgii</i> , Wright. <i>Myacites Jurassi</i> , Brong. <i>Ctenostreon pectiniforme</i> , Sow. <i>Trigonia striata</i> , Sow. <i>Gresslya abducula</i> , Phill. <i>Pholadomya Murchisoni</i> , Sow.	
SOMMERIÆ.		<i>Astarte elegans</i> , Sow. " <i>excavata</i> , Sow. <i>Lima Etheridgii</i> , Wright. <i>Myoconcha crassa</i> , Sow. " <i>implana</i> , Whidb.	
DISCITIÆ.		<i>Modiola Souverbyana</i> , d'Orb. ? <i>Myoconcha crassa</i> , Sow. " <i>implana</i> , Whidb. ? <i>Ceromya bajociana</i> , d'Orb.	<i>Serpula plicatilis</i> , Münster attached to <i>Terebratulæ cortensis</i> and <i>Z. Eudesti</i> .
CONCAYI.			
BRADFORDENSIS & MURCHISONÆ.	<i>Pleurotomaria</i> 1 <i>Mopsa</i> , d'Orb. <i>Stoddarti</i> , Tawney. + " <i>dundrensis</i> , Tawney. " <i>niortensis</i> , d'Orb. " cf. <i>subdecorata</i> , Mün. " <i>Angulus</i> , d'Orb. " <i>punctata</i> , Sow. + <i>Cirrus nodosus</i> , Sow. + " <i>pyramidalis</i> , Tawney. + " <i>Leachi</i> , Sow. + " <i>Catisto</i> , d'Orb. " <i>Amberleya</i> ( <i>Turbo</i> ) <i>Stoddarti</i> , Tawney.	<i>Trigonia striata</i> , Sow. <i>Myacites</i> aff. <i>Jurassi</i> , Brong. ? <i>Opis trigonalis</i> , Sow. ? <i>Cypriocardia cordiformis</i> , Desl.	
OPALINI & ALENSIS.		<i>Lima</i> aff. <i>Etheridgii</i> , Wright. <i>Pholadomya filicula</i> , Sow.	
DUMORTIERIÆ to FALCIFEÆ.		No species have been recorded.	
SPINATI & MARGARITATI.		<i>Pseudopecten agnivalvis</i> , Sow. <i>Gryphæa cymbium</i> , Lam.; or <i>Ostrea gigantea</i> . <i>Arcula</i> .	

<sup>1</sup> There is some doubt as to the correct date of these Dundry *Pleurotomaria*, the character of the matrix of specimens in the Bristol Museum, in this as in many other cases, being all the evidence available.



VIII. REMARKS ON THE IMPORTANT FEATURES OF THE  
DUNDRY STRATA.

Some of the more striking features of the Dundry rocks call for special notice on our part; and with these remarks we shall have a few words to say about the contemporaneous deposits in other districts which are comparable with those of Dundry.

## (1) The Marlstone Rock.

The first intimation which we had of the presence of the Marlstone Rock at Dundry, or rather of the existence of a deposit laid down during the *spinati* hemera, was in receiving from a quarryman a very good specimen of *Pleuroceras* aff. *nudum* (Quenstedt). This man said that it came from the 'Ironshot Oolite' in one of the quarries on the hilltop: it certainly came from an ironshot oolite; but the colour and softness of the matrix showed that it was not the Ironshot Oolite,—the rock deposited during the *Sauzei* hemera. Further, the specific and generic determination convinced us that the species lived contemporaneously with *Pleuroceras spinatum*. How or where the quarryman obtained it we know not, and we have never been able to learn. We then knew of no Marlstone exposed at or near Dundry itself; and we know of none now to the west of the main road.

Since then we have found Marlstone Rock; first at Maes Knoll on the western side of the camp,<sup>1</sup> towards the base of the steep escarpment, well within what is marked *g* 5, Inferior Oolite, in the Geological Survey map. Next we found the rock well shown in a farmyard by the side of the road at East Dundry; and here again the line for Inferior Oolite on the Survey map is carried well below the Marlstone outcrop. Further, the Marlstone Rock crops out on the hillside below Watercress Farm, and it has been disclosed in field-drains opposite the Rookery. On the northern side of the escarpment from New Down Lane by East Dundry to Maes Knoll, it is shown at various points in the fields—often slipped or tilted blocks—and the '*bifrons*-beds' are occasionally shown resting upon it (see Section VI A. p. 684). Immediately west of the corner of the little spinney south-west of Maes Knoll Tump the Marlstone Rock is well shown as a massive bed 2 feet 10 inches thick; and the same bed, as slipped blocks, is seen again for some distance along the southern side of the spinney. Yet again, in the lower part of this wood it is exposed in several places *in situ*, and once more near the base of the escarpment 70 yards east of the spinney. For the sections of these latter exposures see p. 686—Section of Maes Knoll. In addition to these places we have found outcrops of the Marlstone Rock at several other points, but only in the

<sup>1</sup> It was a brown ironshot stone and was conglomeratic, containing derived lumps—among them a blue stone with crinoids. It yielded belemnites, and what was determined as *Pseudopecten equivalvis*.

eastern portion of the hill, that part which lies east of the Chew Stoke Road.

The general characters of the rock may be stated as follows:—Coarse, yellowish-brown, ironshot oolite—the oolitic feature almost universally present, but most strongly developed in the upper portion of the rock,—distinguished by the presence of the species noted in our faunal lists.

It was probably the ironshot-oolitic character which deceived the officers of the Geological Survey, as it has doubtless misled geologists subsequently; but the fossil evidence is clear, moreover it is fairly abundant, and so too are the exposures about the eastern part of the hill. Yet, as a matter of fact, round the greater part of the hill the boundary-line of the Inferior Oolite on the Survey map is carried well below the outcrop of the Marlstone—just as far below, in fact, as would have been correct had the Marlstone been actually ‘the Ironshot Oolite’ of the *Sauzei* hemera.

## (2) The Blue Ironshot-beds.

In order to be precise we have called the hard deposits lying upon the Marlstone, or separating the upper and lower clays where the Marlstone is absent, ‘the Blue Ironshot-beds,’ from the noticeable characters of the matrix; but colloquially we have spoken of them at times as ‘the Cephalopod-bed,’ because in part these deposits are contemporaneous with part of the Cotteswold Cephalopod-bed, at other times as ‘the *bifrons*-beds,’ because of the presence of *Hildoceras bifrons*.

The series of deposits forming the so-called ‘Blue Ironshot-beds’ were exposed by excavations at the western end of the hill and at Maes Knoll; and at many other places on the flank of the hill these deposits have been found, recognizable by their peculiar matrix and the contained fossils. At the western end the strata are very thin, but nevertheless furnish evidence of deposits laid down during the following hemeræ: *falciferi*, *bifrontis*, *striatuli*, *fallaciosi*—so that there is wanting any deposit made during the *variabilis* hemera.

At Maes Knoll the beds are thicker; but it is evident that the deposit is of a fairly uniform and persistent thickness throughout the range of the hill. At the latter place a very good section was obtained by excavation, showing a clear sequence of deposits during the hemeræ noted above and during that of *variabilis* as well; in fact the deposit of this latter hemera is very distinctly marked by fossils. As to the other beds, perhaps it would be more correct to say that the deposit laid down during the *bifrontis* hemera is not present at Maes Knoll, but that it has been removed and redeposited during the *variabilis* hemera.

As to the correspondence of this bed or series of beds with those of the Cotteswolds, it may be seen in Table VI., facing p. 704; but we may note that the deposit separating the beds of the *falciferi* and *striatuli* hemeræ at Maes Knoll is only 18 inches in thickness,

partly, no doubt, owing to the break-up of the *bifrons*-bed and redeposition, whereas the deposit during the same length of time at Frocester Hill, ascertained by S. S. Buckman by some recent measurements, is as much as 264 feet in thickness.

With regard to the rest of the Cephalopod- or Blue Ironshot-bed of Dundry Hill, it may be noted that only the deposits of the *striatuli* and *dispansi* hemeræ are contemporaneous with the Cotteswold 'Cephalopod-bed'; that they are equivalent only to the lower portion of that bed, because the Cotteswold Cephalopod-bed shows deposits made during the following hemeræ: *striatuli*, *dispansi*, *Dumortieræ*, *Moorei*, *aalensis*—so that it is equivalent in point of time to the Blue Ironshot-beds (upper part), the *Dumortieria*-beds, and the basement portion of the limestone series of Dundry Hill.

### (3) The *Dumortieria*-beds.

It is certainly rather singular that the inappropriate nature of the term 'Midford Sands,' from a lithological point of view, should be shown by a locality so close to Midford as is Dundry Hill. The distance from Midford to Maes Knoll is only  $10\frac{1}{2}$  miles; yet the deposit which would be called 'Midford Sands' at Dundry is a clay called by us the '*Dumortieria*-beds,' resting upon a thin ironshot limestone, and this latter deposit is contemporaneous with some 30 feet of the lower portion of 'the Sands' at Midford.

With a thickness of some 50 to 60 feet the clays of the *Dumortieria*-bed are to be found all round Dundry Hill, immediately below the Limestone Series or so-called 'Inferior Oolite'; and they may be known by such surface-indications as fruit-trees, springs of water, and so on. They yield a good pasture, and thus, instead of the fir-trees and waste land which occupy the sandy slopes of the Cotteswold Hills, there are, at Dundry, grass-fields and occasional orchards at about the same geological level.

The *Dumortieria*-beds are, in point of date, contemporaneous with the middle portion of the Cotteswold Cephalopod-bed, and, judging by the evidence at North Stoke<sup>1</sup> near Saltford, with the upper part of the Midford Sands.

But we must note that the term 'Midford Sands' has been used in two different senses. It is employed in a wide sense to embrace various non-contemporaneous sandy deposits laid down from the latter part of the *bifrontis* hemera until the *opalini* hemera inclusive; while in its restricted sense it is only a local name for certain sandy beds in the neighbourhood of Bath, of the date of the *dispansi* hemera so far as the earlier part is concerned, and the later portion—judging by the evidence of North Stoke—of the date of the succeeding *Dumortieræ* hemera. Taken in a restricted sense, the Midford Sands are well represented at Dundry by a thickness of 50 to 60 feet of strata,—which is very different from what our predecessors have stated; but at Dundry they cannot be

<sup>1</sup> North Stoke is 7 miles eastward from Maes Knoll.

called 'Sands' at all—they are truly clay. These beds are undoubtedly the Upper Lias of some previous observers, while the *Terebratula Eudesi* and *concaum*-beds were their 'Midford Sands.'

As to the thickness of the strata of the *Dumortieria* hemera at Dundry as compared with the Cotteswolds, we find the opposite to what obtained in regard to the last comparison—the *variabilis*-beds; but it is not so pronounced. Dundry shows 50 to 60 feet, as against the Cotteswold deposit, which is often only a few inches in thickness, but does reach to as much as 8 feet at North Nibley.

The sequence of ammonites found to obtain at Dundry Hill from the time of *bifrons* to that of *Dumortieria* is just the same as that which was first pointed out by one of us<sup>1</sup>, and has since been proved over so large a part of Europe.<sup>2</sup>

#### (4) The Strata of Aalenian Age.

At Dundry there is evidence, in a bluish stone at the base of the so-called 'Inferior Oolite' limestone, of a deposit containing ammonites of the *Grammoceras-aalense* type, contemporaneous with the upper part of the Cotteswold Cephalopod-bed. We have, however, no very definite evidence of any deposit during the *opalini* hemera, nor during the *scissi* hemera, which is so noticeable in the Cotteswolds as the "Sandy ferruginous limestone."

At Dundry we have evidence of the deposit of rock during the *Murchisonæ* hemera, but we have little testimony as to any deposit during the *bradfordensis* hemera; this is partly owing to the want of exposures and the intractable nature of the rock. The deposits of the date of *Murchisonæ* (and perhaps *bradfordensis*) are thin, like the contemporaneous deposits in Dorset, whereas in the Cotteswolds the contemporaneous strata attain a very great thickness (150 feet or more), and their subdivisions can be noted easily.

#### (5) The Strata of Bajocian Age.

The presence of the *Sonninia fissilobata-ovalis*-type of ammonite at once marks a certain horizon at Dundry as contemporaneous

<sup>1</sup> S. S. Buckman, 'On the Cotteswold, Midford, and Yeovil Sands,' Quart. Journ. Geol. Soc. vol. xlv. (1889) p. 440; extended and added to in 'Monograph Inferior Ool. Ammonites,' Pal. Soc. vol. xlv. (1890) p. 164; and 'On the Jurenses Zone,' Journ. Northants Nat. Field Club, vol. vi. (1890), list of species peculiar to the different divisions.

<sup>2</sup> Louis Brasil, 'Sur le Lias supérieur et le Bajocien de Tilly-sur-Seulles et Feuguerolles,' Bull. du Laboratoire de Géol. de la Faculté des Sciences de Caen, vol. ii. p. 167, 1893; 'Les Divisions de la Zone à *Lytoceras jurenses* en Normandie,' Bull. Soc. Linn. Normandie, ser. 4, vol. ix. fasc. 1, p. 34, 1896; also 'Remarques sur la Constitution du Toarcién supérieur dans le Calvados,' *ibid.* fasc. 2, p. 147, 1896.

Emile Haug, 'Jurassique,' La Grande Encyclopédie, p. 322, Paris, 1895.

Jules Welsch, 'Sur la Succession des Faunes du Lias supérieur et du Bajocien inférieur dans le détroit du Poitou,' Compte-rendu de l'Académie des Sciences de Poitiers, 1895.

Chartron et Welsch, 'Sur la Succession, etc., dans les environs de Luçon (Vendée),' *ibid.* Aug. 1896.

with the lower part of the fossil-bed at Sandford Lane near Sherborne, and with the Gryphite Grit of the Cotteswolds. The middle part of the Sandford Lane Fossil-bed contains numerous species of *Witchellia*; similar species of the same genus are found at Dundry above this *Sonninia fissilobata-ovalis* horizon, in a bed of different matrix; and they are found in the Cotteswolds in a bed lithologically different from, and some 12 to 25 feet above the Gryphite Grit (*fissilobata-ovalis*): so that the correspondence in this case is very noticeable. Then the upper part of the Sandford Lane Fossil-bed contains a peculiar fauna—consisting of *Sonninia* of the *propinquans*-type, high-keeled species noticeably different from *fissilobata*—and ‘*Stephanoceras*’ *Sauzei*, or *contractum*; and the same suite of fossils is found at Dundry above the *Witchellia*-series in an unmistakably different matrix. No deposit of this date can yet be definitely stated to have been found in the Cotteswolds, yet at Cleve Hill there is, above the *Witchellia*-grit, some 25 feet of rock which it is reasonable to suppose was laid down during the *Sauzei* hemera, simply because of the position which it occupies in the stratigraphical sequence.<sup>1</sup>

Above the Ironshot Oolite—the deposit of the *Sauzei* hemera—there is at Dundry a non-sequence, just as there is at Cleve Hill, and at Sandford Lane, near Sherborne; but at Osborne, near Sherborne, are found the deposits laid down in this interval; and these are noted in Table VI., facing p. 704.

#### (6) The Strata of Bathonian Age.

Of the date of the deposit which follows the stratigraphical gap in the sequence of the Dundry rocks we have a certain amount of evidence from contained fossils: it was laid down during the *Garantianæ* hemera. Therefore it is contemporaneous with the Upper *Trigonia*-grit of the Cotteswolds, which also follows the stratigraphical gap so noticeable in that district; and it is contemporaneous with the Freestones of Sherborne (Dorset).

Of the exact date of the remaining Dundry deposits we have not much evidence. We have, of course, that of their position in the stratigraphical sequence, and we have the brachiopod evidence of the Coralline beds. The inferences to be drawn therefrom we have stated on p. 680, etc.

In the Freestones and Coralline beds, but in the latter more particularly, there is a considerable amount of siliceous matter which no doubt adds materially to their hardness. There is chalcedony with geodes containing quartz-crystals, as well as incrustations of beekite.

#### (7) The Geographical Extent of the Ironshot Oolite.

The Ironshot Oolite has been found by us only at the northern and southern main-roadside quarries, at Rackledown, at East

<sup>1</sup> S. S. Buckman, ‘The Bajocian of the Mid-Cotteswolds,’ Quart. Journ. Geol. Soc. vol. li. (1895) p. 461.

Dundry, and  $\frac{1}{2}$  mile to the east thereof. It is known to be absent at Clements' Yard, Barns Batch Spinney, and Maes Knoll. Therefore in a westerly direction it has been removed entirely in  $\frac{1}{2}$  mile from the main road, and in an easterly direction it probably fails in about  $\frac{3}{4}$  mile east of East Dundry. North and south it is cut off by the escarpment. Consequently the Ironshot Oolite occupies an area in the middle of the hill only, and its extent cannot be more than  $1\frac{3}{4}$  miles long (from east to west) and about 1 mile wide (from north to south). The reason for the limited east-to-west extension of the Ironshot is in all probability denudation soon after its deposition, to which the flat top of the Ironshot itself bears witness; and the planed-off top of other beds where the Ironshot is not present also tells the same tale. The theory of a limited area of original deposit in regard to the east-and-west extension would involve the hypothesis that the sea-bottom of the western portion of the hill was elevated after the deposition of the Lower White Ironshot (*Sonninia hemera*).

#### (8) The Geographical Extent of the Freestone.

This is a matter of considerable economic importance. We are able to show that the Freestone thins away very rapidly, and also loses the freestone character, as we proceed from Dundry Church eastward—the Northern Main-road quarry (Section IV.), and south-eastward—the Southern Main-road quarry (Section IX.). These beds thin away and deteriorate so rapidly that it is very doubtful whether workable building-stone of good quality would be found  $\frac{1}{4}$  mile east of the church. Westward, on Dundry Down, the old workings for freestone are very numerous, occupying a considerable area, and it is probable that nearly all the good stone has been obtained in that direction. There remains, however, the ground east of the Down and south of the church, an area about equal in extent to that which has been worked for stone; and this may certainly be expected to yield freestone of good quality. Farther south, in the direction of Barns Batch, there is a considerable thickness of stone, but its quality would seem to be inferior to that of the Freestone proper. It is unfortunate that for want of suitable exposures we are not able to give more precise details concerning the construction of the hill between the Winford road and Barns Batch; but it is obvious that the area over which workable freestone is likely to be found is a very restricted one. Our investigations indicate that it certainly extends very little to the east or south-east of the village, and certainly is wholly confined to the portion of the hill westward of the main road.

Concerning the qualities of the Dundry Freestone, the following works may be consulted:—

LLOYD MORGAN, Prof. C., 'On Bristol Building-Stones,' Proc. Bristol Nat. Soc., N.S., vol. v. pt. ii. pp. 98, 102, 104.

HULL, Prof. E., 'On the Building and Ornamental Stones of



Great Britain,' London, 1872, p. 209; and p. 318 gives the weight of a cubic foot of Dundry stone.

For analyses of the Dundry Freestone see

VOELCKER, Prof. A., Journal of the Bath and West of England Agric. Soc., New Series, vol. vi. p. 223; Mem. Geol. Surv. vol. ii. (1848) pt. 2, p. 688.

### IX. THE BAJOCIAN DENUDATION.<sup>1</sup>

Nowhere at Dundry Hill is the sequence of Bajocian strata complete; there is, even at the main-road quarries, where deposits have been laid down during the greatest number of hemeræ, a break in their sequence, so that the succeeding bed rests non-sequentially upon the planed-off surface of the Ironshot Oolite.

The portion of the Dundry strata which suffered least from Bajocian denudation is that lying between the main road on the west, and East Dundry and Rackledown on the east. Westward of this the Bajocian denudation has removed two important fossiliferous beds, namely, the Ironshot Oolite and the *Witchellia*-bed. East of this area there are unfortunately no exposures until Maes Knoll is reached, when the effects of denudation are very striking. The Ironshot and all the limestone-beds which underlie it at Dundry have been removed; and further denudation must have taken place here in Bathonian time while deposition was going on quietly at the western end of the hill, for at Maes Knoll there is a conglomeratic bed of the date of the *Garantianæ* hemera containing shells of the *Dumortieria* hemera.

Farther eastward, at North Stoke, a similar deficiency in the stratigraphical sequence occurs, due in part at any rate to Bajocian denudation. There the strata of the *Garantianæ* hemera rest upon about 8 feet of sands deposited during the *Dumortieria* hemera. A similar non-sequence of deposits is found at the Barrow Hill, and at Midford, near Bath. Then, in a northerly direction, from Bath to Cheltenham, the *Garantiana*-bed is still found resting non-sequentially on an earlier deposit; but the gap in the sequence decreases as the distance to Cheltenham lessens, until near that town strata contemporaneous with the *Witchellia*-bed of Dundry are once more found beneath the deposit of the *Garantianæ* hemera.<sup>2</sup>

South-east of Dundry, however, some striking facts concerning non-sequence of deposition were obtained. At Wellow, near Radstock, 10 miles E.S.E. of Maes Knoll, the deposit of the *Garantianæ* hemera rests in some cases upon clay of a pre-*falciferi*

<sup>1</sup> It should be noted that the term 'Bajocian denudation' does not mean denudation of rocks of Bajocian Age, which might have happened at any date, but a denudation (of any rocks) which was effected during the Bajocian Age. In the present case, so far as Dundry is concerned, the denudation doubtless began towards the close of the Bajocian Age, and ended at the beginning—before the second hemera—of the Bathonian Age. But there is evidence at other places that it continued during the second hemera of the Bathonian Age.

<sup>2</sup> S. S. Buckman, 'The Bajocian of the Mid-Cotteswolds,' Quart. Journ. Geol. Soc. vol. li. (1895) p. 416.

hemera in date; but in other cases pockets of later deposits have been left to tell the tale of what was once laid down there. We visited the section and made the following observations, which may be of interest for comparison with Maes Knoll:—

SECTION XI.—*Wellow. First cutting on the Somerset and Dorset Railway towards Radstock.*

		ft.	ins.	ft.	ins.
	1. Cream-coloured, crystalline, coarse-grained limestone, <i>Terebratula globata</i> (Cotteswold type), about 5 feet up. Several feet thick.				
GARANTIANÆ.	2. Yellowish, very strongly ironshot stone, the grains not so large as in bed 5. <i>Acanthothyris spinosa</i> , <i>Nerinea Guisei</i> . Small <i>Astarte</i> and lamellibranchs ...	0	4		
	3. Hard iron-specked limestone with iron markings, irregularly but firmly cemented to bed below .....	0	2		
				0	6
DUMORTIERIE?	4. A greenish-pink, arenaceous stone, from 1 to 3 inches in thickness, much bored by <i>Lithodomi</i> .....			0	3
DISPANSI ? to BIFRONTIS.	5. Yellowish, very strongly ironshot stone. <i>Hildoceras bifrons</i> , <i>Grammoceras doernitense</i> .....	0	2		
	6. Ironshot, bluish-grey limestone with <i>Hildoceras bifrons</i> , <i>Dactylioceras</i> , <i>Rhynchonella</i> cf. <i>Moorei</i> .....	0	4		
				0	6
FALCIFERI.	7. Pinkish, argillaceous stone with iron specks containing ammonites indicative of the <i>falciferum</i> and perhaps <i>bifrons</i> horizons .....			0	8
	8. Blue clay, visible in the next cutting towards Radstock <sup>1</sup> ..... about			20	0

At the place where the section was measured Beds 3 & 4 were not found, so that Beds 2 & 5, both remarkable ironshot beds, came into actual contact, with the result that the same block of stone, only a few inches thick, yielded *Hildoceras bifrons* and *Acanthothyris spinosa*. The statement that these two species occurred together would have been deemed incredible, although it is true enough in the present case. Their occurrence together does not, however, prove that they were contemporaneous; yet such a supposition has led to much futile argument about inosculation of zones. Really the explanation in this case is simple. It is known from the evidence of many other localities that an immense interval of time must have elapsed between the existence of *Hildoceras bifrons* and the time when *Acanthothyris spinosa* lived. Therefore whatever deposit accumulated above the bed with *Hildoceras bifrons* must have been removed down to that level before the deposit of the *Acanthothyris spinosa* date was laid down. That there was such removal is shown in parts of this cutting, for, as stated above, the full sequence was

<sup>1</sup> There is no evidence as to the date, but presumably this is the same clay as that proved at Maes Knoll, Section VII B, No. 17.

not found where the section was measured, but the missing beds, Nos. 3 & 4, were found 35 yards eastward. Still farther east all the beds numbered 3 to 7, inclusive, were absent, and Bed 2 was separated from Bed 8 only by a thin band of a blackish dense stone. To the west in the same cutting a somewhat crystalline stone, presumably representing Beds 1 & 2, rests on about 4 inches of the *falciferum*-bed No. 7; so that here Beds 3 to 6 are absent. Still farther west, and also in the next cutting towards Radstock, Beds 3 to 7 have but narrowly escaped total denudation, and they remain as relics of the destruction which took place prior to the deposition of the strata of the *Garantianæ* hemeræ.

#### X. THE WATER-BEARING BEDS OF DUNDRY HILL.

Springs issue at two principal levels, and occasionally at two or three others, on the upper slopes of Dundry Hill. The chief level for large springs is at the top of the shales of the *Dumortieria*-beds, the water often welling forth in streams of considerable volume and of great persistence where the Aalenian limestones rest upon these impervious argillaceous strata. This is the chief water-bearing bed of Dundry village; in fact, it is because the *Dumortieria*-beds are clay that the houses of Dundry occupy their present position: had the *Dumortieria*-beds been sands, the water-bearing surface would have been nearly 50 feet lower down than it is now.

The level next in importance for springs is the base of the Marlstone Rock, from which water is thrown out at various points along the eastern portion of the northern escarpment and also on the sides of the valley below East Dundry.

At certain points on the western side of the hill, where the Marlstone is absent, or, if present, exists in so fluctuating and attenuated a form as to have hitherto escaped detection, springs occasionally break out from the '*bifrons*-beds': the Elwell spring, south of Castle Farm, is an example. The '*Cephalopod*-bed,' or '*bifrons*-beds,' also often gives out small springs on the hillside, both on the northern and the southern escarpment. Moreover, small springs occasionally break out from the grey sandstones in, and especially near the base of, the *Dumortieria*-clays: several of the drinking-pools for cattle are thus supplied. Such is the source of the small spring just above the Elwell spring; of another spring at the old and dismantled Pickwick Farm, west of Maes Knoll; while until recently there was a small spring visible in these beds on the right-hand side of the main road, immediately south of the Butchers' Arms.

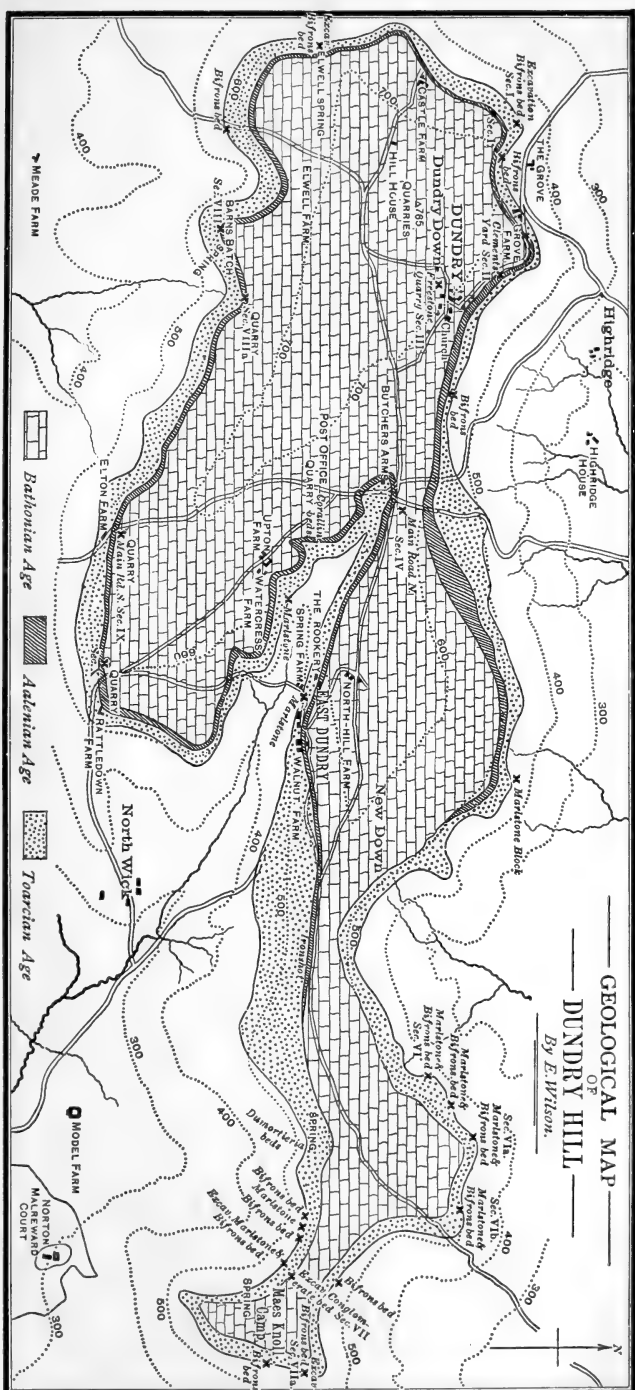
Another occasional level for water is formed by the shales with *Terebratulæ Eudesi*—that is, at about the junction of the strata of Bajocian age with those of Aalenian date, one of these being just below Castle Farm on the western escarpment.

Some of the smaller springs dry up altogether in the middle of summer, or in very dry seasons; but the larger springs of Dundry Hill are remarkably persistent.

## XI. THE MAP OF DUNDRY HILL.

With this communication we present a geological map of the different deposits and their superficial extent as found by us to obtain at Dundry Hill. As the map of the Geological Survey shows round so very much of the hill the Marlstone of the Middle Lias, and even beds below that, coloured as if they were Inferior Oolite, our map is, we consider, of value in that it amends the official document. But we claim that it is of importance in another respect. That different lithological conditions prevailed at the same time in closely contiguous areas is an accepted fact; and as a consequence, palæontological divisions do not coincide with divisions founded on lithological characters, as one of us (S. S. Buckman) has repeatedly urged in a series of papers on the Jurassic rocks. We show in the present paper that this non-agreement between the palæontological and the stratigraphical methods obtains at Dundry compared with surrounding areas; and therefore the divisions accepted by us in our mapping are based upon purely palæontological lines. We present therefore what is really the first Jurassic map of any area in which such divisions have been represented. The divisions which we have adopted are as follows; and in order that they may be compared with the divisions adopted in their maps by the officers of the Geological Survey, we place the two side by side:—

Quenstedt's Divisions in Germany (stratigraphical and palæontological).	The present Divisions (chronological, based solely on palæonto- logical evidence).	The Geological Survey Divi- sions (stratigraphical).
Brauner Jura ζ .....	} Bathonian .....	{ From the upper portion of the Inferior Oolite up to the Kellaways Rock inclusive.
Brauner Jura ε .....		
Brauner Jura δ ( <i>pars</i> ). .....		
Brauner Jura δ ( <i>pars</i> ). .....	} Bajocian .....	Inferior Oolite ( <i>pars</i> ).
Brauner Jura γ .....		
Brauner Jura β .....	} Aalenian .....	{ Inferior Oolite ( <i>pars</i> ). Midford Sands ( <i>pars</i> ).
Brauner Jura α .....		
Schwarzer Jura ζ .....	} Toarcian .....	{ Midford Sands ( <i>pars</i> ). Upper Lias.
Schwarzer Jura ε .....		
Schwarzer Jura δ, etc.	Charmonthian .....	{ Middle Lias. Upper part of Lower Lias.



[Scale : 2 inches = 1 mile.]

*Note.*—The geological boundaries were placed on the 6-inch map of the Ordnance Survey, on which this sketch-map is based.

As a matter of fact, so far as Dundry is concerned, the line which we draw to mark the commencement of deposition in Aalenian time should coincide with the line which the officers of the Geological Survey have drawn as the base of the Inferior Oolite. That there is not always such coincidence is due to the error about the Marlstone already alluded to (pp. 683, 706). Then the area enclosed by our Bathonian-Aalenian lines represents what would be called 'Inferior Oolite, *g* 5,' so far as Dundry Hill is concerned; and the limits that we have laid down may be regarded as = 'Inferior Oolite' planned to the best of our ability.

As to what our terms 'Aalenian,' etc., represent, the reader is referred to Table IV., facing p. 696. Of course, only the commencement of the Bathonian age is now represented by deposits at Dundry. The deposits of Bajocian age there are so incomplete and so meagre that we have not attempted to map them separately, and therefore the Bajocian beds are, as a matter of fact, marked Aalenian; but their outcrop-area is so small that this is not a matter of importance.

Our method of procedure in regard to the mapping was as follows:—We paid two or three visits to the hill in company, and decided the limits of our divisions at certain of the more important points. The mapping of the intermediate country was done by one of us (E. Wilson) alone, tracing the deposits of the different hemeral series round the hill as opportunities for the numerous necessary visits arose. Then one or two of the exceptionally difficult and doubtful portions where exposures are wanting, and everything was hidden beneath a continuous cloak of grass, were re-surveyed in company.

Owing to a deficiency of exposures or of any clear physical feature, it has been found impossible to determine with precision the limits of the *Dumortieria*- to *spinati*-beds round the Rackledown projection, for some little distance along the southern side of the escarpment between East Dundry and Maes Knoll, and also for some little distance east of the drinking-trough on the Chew Stoke road,  $\frac{1}{2}$  mile east of Dundry village, on the northern side of the plateau; and the lines drawn on our map for these portions of the area must be looked upon, therefore, as to a certain extent conjectural.

In the western portion of the hill—*i. e.* west of the main Chew Stoke road—owing to the absence or non-appearance of the Marlstone Rock, the Toarcian base-line had to be defined by the *bifrons*-bed, which, being too insignificant of itself to form an appreciable surface-feature, made it impossible for us to do more than draw in this line to a certain extent conjecturally: the chief evidence for it being furnished by the presence, at a level of about 50 feet below the base of the Aalenian Series, of the *bifrons*-bed in springs, road-cuttings, hillside scars, and our special excavations made at the western end of the hill.

Concerning the natural features of the surface-configuration of Dundry Hill, the following remarks may be made:—

The edge of the hill, which may be as much as 100 feet below the highest ground on Dundry, is defined by rocks of Bathonian age

forming a steep and well-marked escarpment on the northern and western faces of the hill, and a very bold one above the valley west of East Dundry and round the Maes Knoll promontory; but this feature is much less clearly defined, and often quite indistinct, on the southern face of the eastern portion of the hill and round the Rackledown projection. The greater hardness of the rocks of Bathonian age (to which date, it is to be remembered, we assign the Freestones of Dundry), relatively to the underlying deposits, gives a steeper slope to the upper edge of the escarpment, so that we generally find a projecting brow of these rocks above the somewhat softer strata of Bajocian-Aalenian date. It is often hard to define with precision the base of the 'Upper (Bathonian) beds,' partly owing to the limited number of exposures at the right level, and partly because much of their rubble has travelled some distance down the hillside, concealing the outcrops of the underlying strata.

The strata of the Bajocian-Aalenian ages, which are also a variable series, owing in part at any rate to pre-Bathonian denudation, form, where they are present, the lower and generally less steep upper portion of the escarpment, or even a slight terrace.

The *Dumortieria*-clays, deposited during the Toarcian age, are readily worn back, and hence they usually give a very steep, sometimes almost mural slope beneath the overlying protecting beds. Slopes of this kind are found beneath Dundry village, and around the Maes Knoll promontory.

At a distance of from 50 to 60 feet below the lower limits of the strata of the Bathonian-Aalenian ages, a second lower and minor escarpment or terrace may frequently be noted. This escarpment is determined either by the Marlstone Rock, by the '*bifrons*-bed,' or by some hard beds in the lower portion of the *Dumortieria*-clays a little above that bed. The feature made by the Marlstone Rock is often well defined in the eastern portion of the hill, *e. g.* at various points along the northern escarpment east of the northern end of Newdown Lane, directly beneath East Dundry, and around the upper portion of the East Dundry Vale.

Below the Marlstone terrace the ground formed of soft clays of the Charmouthian age, with few hard beds in them, slopes away at a much gentler angle than the clay ground above the Marlstone slopes down to that rock.

It may be noticed that the beds of Dundry are synclinal, especially from east to west. This synclinal feature probably accounts for the lower level at which the strata of the Bathonian age lie near East Dundry compared with Maes Knoll. On the edges of the escarpments there is evidence of local faulting or slipping over, as for instance at Barns Batch, and the northern main roadside quarry: while dip-slope towards the escarpments, and not any exaggerated thickness of the beds, probably accounts for the much lower level which the strata of Bathonian age (Coralline, etc.) occupy on the edges as compared with the middle portion of the hill—as, for instance, the northern and north-eastern margin of the main hill, and the eastern slopes of the Rackledown spur.

(1) Comparison of the Geological Survey Map<sup>1</sup> with the one here presented.

The Geological Survey map represents at Dundry only Inferior Oolite resting upon Lower Lias. The boundary-line which we shall have to notice is that drawn separating the deposits so classed. Beginning at the main road on the northern flank of the hill, and going westward, the Survey's boundary-line of Inferior Oolite coincides with our own (beginning of deposition in Aalenian age), and is drawn at the top of the *Dumortieria*-clays, along by the village and 'The Grove,' until about 250 yards north of Castle Farm, when it strikes off to the top of the 'Cephalopod-' or '*bifrons*-beds'; and at Castle Farm it is about 150 yards outside our line. It continues on or a little below this horizon round the southern flank of the hill to Rackledown Farm, when it drops below the Marlstone—as much below, in fact, as it ought to be if the Marlstone were really the Ironshot Oolite of the *Sauzei* hemera. It continues at this level round both sides of the East Dundry Valley, with the result that the Survey base-line of Inferior Oolite is, at the head of the valley, as much as 650 yards outside ours.

Their boundary-line then continues to run on this infra-Marlstone level to Maes Knoll, where in drawing our line we differ from the Survey to the extent of about 100 feet in vertical thickness, and in some places, as at the north-eastern corner, to the extent of about 250 yards in horizontal distance.

From Maes Knoll their boundary-line continues along the northern flank of the hill on the infra-Marlstone level until it approaches the main road whence we started, when they show a lengthy northward prolongation of 'Inferior Oolite' by the eastern side of the bend in the main road. This projection is not only some 400 yards outside the boundary of what they call Inferior Oolite across the road, but it is even some 250 yards outside what we take to be the horizon of the Marlstone.

It will thus be seen that, except along the northern flank of Dundry Hill, to the west of the main road, the Survey have mapped far too great an area as Inferior Oolite, and as a consequence have given too great a vertical thickness to the 'Inferior Oolite.' The latter result of course obtains more at Maes Knoll than elsewhere, because there only a very thin capping of strata of Bathonian age is left to represent the 'Inferior Oolite.'

(2) Comparison of Sanders's Map<sup>2</sup> with our own.

Commencing at the main road, as before, Sanders shows the base of the Inferior Oolite at the top of the Marlstone; then the line rises,

<sup>1</sup> Sheet XIX., 'Geological Information revised, and Penarth Beds surveyed, by H. W. Bristow, H. B. Woodward, W. A. E. Ussher, and J. H. Blake, 1867–1871. New edition. Published May 1873.'

<sup>2</sup> Sanders, William: 'Coalfields of Bristol and the Country adjacent geologically surveyed.' Folio manuscript, 1862. Map published on the scale of 4 inches to 1 mile; republished by Lavars & Co., Bristol, on the scale of 1 inch to 1 mile.



and is carried along about the middle of the *Dumortieria*-beds all round the hill until it meets the main road at the south, by Elton Farm, when it drops to the Marlstone level. Thence it is carried at this horizon until a little east of Watercress Farm, on the southern flank of the East Dundry Valley. Here it begins to rise gradually, and at the head of the valley, at the Butchers' Arms, it reaches the top of the *Dumortieria*-beds, so that here it coincides with our own map and differs seriously from that of the Survey. Returning, on the northern flank of this valley, it drops to the Marlstone level just before East Dundry is reached, and along that horizon it is continued until above Northwick Cottages. Here Sanders's Inferior Oolite line makes a large outward bend, as much as 500 yards outside our Marlstone limit. Then it returns to the Marlstone level, at about the middle of the bend before reaching Maes Knoll, and is carried at about this level round the hill until the main road on the northern flank is again reached. It does not show that great bend at this point which is so conspicuous on the Survey map.

It will be seen, therefore, that Sanders's map, although of earlier date, approximates more closely to our own than does that of the Survey, and that for the western portion of the hill it is generally only a little outside our 'Inferior Oolite' limit. For the eastern portion of the hill there are considerable differences between our map and his, which, like the Survey map, shows far too great an area as 'Inferior Oolite.'

## XII. SUMMARY.

The following facts and conclusions have been brought forward in this paper:—

1. That at Dundry Hill the sequence of strata laid down during the Bathonian-Bajocian ages is incomplete, because there is no deposit to represent the time of the *niortensis* or *Humphriesiani* hemeræ; in fact, during these hemeræ denudation was in progress at Dundry.

2. That all the strata of the Aalenian and Bajocian ages have been removed from the eastern end of the hill, so that strata of Bathonian date (*Garantiana* hemera) rest non-sequentially upon deposits laid down during the *Dumortieria* hemera.

3. That this removal has been effected by denudation in Bajocian and even post-Bajocian time.

4. That strata equivalent to what are called elsewhere Midford Sands, Upper Lias, and Middle Lias (Marlstone) are present in the hill, the two former attaining a maximum thickness of more than 60 feet, while the Marlstone crops out at many points along the flanks of the range.

5. That the officers of the Geological Survey have apparently confounded the Marlstone Rock (an ironshot oolite of the date of the *spinati* hemera) with the well-known Ironshot Oolite (of the date of the *Sauzei* hemera), a bed nearly 100 feet higher up.

6. That in consequence of this mistake they have, round the greater part of the hill, drawn the base of the Inferior Oolite as far

below the Marlstone as this base ought to have been drawn if the Marlstone were really the Ironshot Oolite or *Sauzei*-bed.

7. That the officers of the Survey have mapped as Inferior Oolite strata which are marked by them elsewhere as Lower Lias, Middle Lias, Upper Lias, and Midford Sands.

8. That the map of Dundry Hill presented with this paper shows the superficial extent of the Inferior Oolite to have thus been greatly exaggerated on all previous maps.

9. That the same sequence of ammonite-faunas obtains at Dundry as in the Cotteswolds and in Dorset, and hence is similar to that found on the Continent.

10. That the *Sonninie* hemera as a distinct period of time with its own fauna preceding the *Witchellie* hemera, as pointed out in the case of the Mid-Cotteswolds, is confirmed by the researches at Dundry.

11. Faunal lists of species found at Dundry are given, and their approximate date of existence is assigned as carefully as circumstances permit. To one of these faunal lists certain palæontological notes are appended, wherein is recorded a new name, *Zeilleria Oppeli*, for one of the forms hitherto called *Zeilleria* (*Terebratula*) *anglica*, attention being drawn to certain difficulties in the original description and to the consequent application of the original name.

12. A section of a railway-cutting at Wellow is given for comparison with certain Dundry sections, and to illustrate the results of pre-Bathonian denudation.

#### DISCUSSION.

Mr. H. B. WOODWARD objected to the application of the Great Oolite term 'Bathonian' to the upper beds of the Inferior Oolite. He pointed out that the Dundry outlier had not been revised since 1845, when the Geological Survey map of the area was published. The differences between the map of De la Beche, Ramsay, and others, and that produced by the Authors were not, after all, very great.

Mr. E. T. NEWTON remarked upon the lists of fossils mentioned in the paper, which included species characteristic of the Middle and Upper Lias as well as of the Inferior Oolite. It was evident that the Authors had detected beds of Middle and Upper Lias age where they had not before been recognized.

Mr. MARR regretted that the Authors were absent, as the summary which he had read appeared much more controversial than the actual paper was. He fully believed in the general accuracy of the detailed work of the Authors, which no doubt was counter to some of the work of earlier observers.

40. *NOTES on the GLACIAL GEOLOGY of ARCTIC EUROPE and its ISLANDS.*  
 —Part II.<sup>1</sup> ARCTIC NORWAY, RUSSIAN LAPLAND, NOVAYA ZEMLYA,  
 and SPITSBERGEN. By Col. H. W. FEILDEN, F.G.S. With an  
 APPENDIX by Prof. T. G. BONNEY, D.Sc., F.R.S., V.P.G.S.  
 (Read June 24th, 1896.)

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## 1. Proof of Changes of Level in Northern Norway.

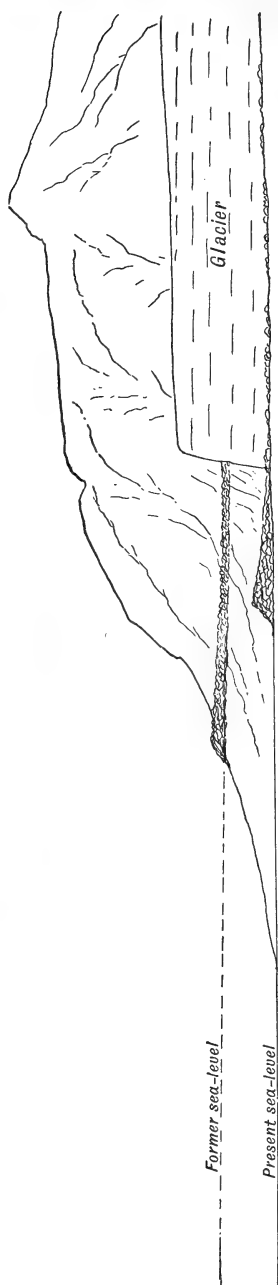
So much has been written about the glacial geology of Northern Norway by great authorities that I should have refrained from discussing the subject had I not recently heard a paper<sup>2</sup> read at a Meeting of this Society, in which the author suggested that the terraces in the transverse fiords of North-western Norway would be perfectly explained by the formation of ice-dammed lakes. The author, however, admitted that the authenticated occurrence of marine organisms in these raised beaches would be a conclusive argument against his views. I have never made any special study of the phenomena connected with the secular upheaval of Arctic Norway, for I had always been under the impression that few geological facts were more generally accepted as well established than the recent elevation of land in Arctic latitudes, including Northern Norway. My observations are consequently somewhat cursory, but I do not remember landing on any of the more considerable islands north of the Arctic Circle, that form the 'Skjergaard' of Norway, without noticing traces of recent elevation and deposits containing abundantly shells of mollusca of the same species as those that now inhabit the adjacent sea. The same holds good of the 'Westeraalen,' and I observed last summer a well-defined raised beach near the settlement of Rissøhavn, on the island of Andø, full of the shells of recent mollusca; this beach was overlain by 4 feet of peaty soil, in which grew birch-trees.

The lofty chain of the Lofoten Islands has not been buried under an ice-cap. Their sharply peaked and serrated mountain-tops, rising from the sea to altitudes between 2000 and 3000 feet, present no evidence of ever having been overwhelmed by the Scandinavian ice-sheet. There are, however, unmistakable signs that at one period of their history great glaciers filled their valleys. The celebrated Trolld Fiord near the western entrance of Raft Sund, the channel between Eastern Vaagø and Hindø, is a narrow but majestic fiord with

<sup>1</sup> For Part I., read Nov. 20th, 1895, see this volume, p. 52.

<sup>2</sup> Boulger, Quart. Journ. Geol. Soc. vol. li. (1895) p. 494.

Fig. 1.—Diagram of Tromsödal terrace, showing the valley when occupied by a glacier.



perpendicular walls of rock on both sides; these, to the height of some 400 feet, are polished and grooved by the action of ice, but the mountain-peaks that rise above the fiord show no signs of glacial abrasion. Attention has been called to this by earlier writers, notably by the late J. F. Campbell<sup>1</sup> and by Prof. Bonney.<sup>2</sup> Passing up Raft Surd, amid some of the finest coast-scenery of Norway, one cannot fail to observe the traces on all sides of former glacial action, especially on the eastern shores of the channel. There nearly every valley descending to the shore-line, now bright with green birch-woods and pastures, has the remains of great moraines at its mouth. Farther north, around Tromsö, the signs of recent elevation are common along the shore-line, and so also the signs of the retreat and disappearance of glaciers which once filled the valleys; but I see no evidence that the mountain-tops on the mainland of this part of Norway have ever been covered by an ice-sheet, even at the time of their maximum glaciation.

The valley of Tromsödal, on the mainland opposite the town of Tromsö, has a conspicuous raised terrace (fig. 1) passing across its mouth, and continued north and south along the present coast-line. This terrace must be  $\frac{1}{4}$  mile wide at the mouth of the valley, and there brick-works are established. In 1894 a good section of this terrace, some 20 feet in height, was exposed, from which the clay used in the works was being taken.

<sup>1</sup> 'Frost and Fire,' vol. i. (1865) nos. 136-137.

<sup>2</sup> Alpine Journal, vol. iv. pp. 430-436; 'Do Glaciers Excavate?' Geogr. Journ. vol. i. (1893) pp. 481-499; 'Ice-Work, present and past,' p. 175, London, 1896.

From base to summit it is a homogeneous mass of blue clay, with boulders and stones interspersed throughout. There is not a trace of bedding throughout the mass. As I considered this deposit to be a typical example of boulder-clay formed under water, I took advantage of my journey in the neighbourhood last summer to revisit the spot. A more careful examination showed that the clay contains ice-scratched stones, and that mollusca are abundant throughout the bed; examples of *Cyprina islandica* and *Pecten islandicus*, partially retaining their colour, are common, likewise stones to which the 'bases' of a *Balanus* are attached. On ascending the terrace, which at its base is only a few feet above present high-tide mark, and looking up the valley, one can realize that apart from its composition it owes its formation to glacial causes. This terrace is flat on the top and at the outer edge slopes seaward, and the same on its opposite side looking up the valley. There can be no doubt that this valley was formerly occupied by a glacier; and when the land stood at a lower level than it does to-day, the front of the glacier was in the sea and the terrace was formed by the material which passed from under the ice, and is therefore a kind of subaqueous moraine.

As we sail from Tromsö towards the North Cape, the course takes us through Kaag Sund and past the island of Arnö. The southern shore of that island is fringed for miles by three great parallel terraces. I roughly estimate Arnö at about 1200 feet in altitude and the terraces at 50, 100, and 150 feet above sea-level. Their position on an island exposed to the full force of a stormy ocean is entirely opposed to the possibility of ice-dams having had any connexion with their construction. In Magerö Sund, which separates from the mainland the island whence juts out the North Cape, sea-worn caves, much above the present sea-level, tell of recent elevation of the land.

The remarkable terraces in the Porsanger and other northern fiords of Norway have been noticed by Bravais, Martens, J. D. Forbes, Chambers, Campbell, Bonney, and others in their descriptions of this part of Norway. The Porsanger is the first of the large fiords that run into the mainland of Finmark. It is about 18 geographical miles in length. The hills on either side are low, probably not more than 500 feet in altitude. They have an ice-planed, ice-smoothed contour. The topographical contrast between this area and the peaked Lofotens and those around and immediately south of Tromsö is striking. The island of Stor Tamsö lies in the centre of the Porsanger Fiord. Its greatest height is probably not more than 300 feet; it is about 7 square miles in extent. Evidently an ice-worn surface, it is entirely or almost entirely covered with a growth of peat, showing a depth in places of 8 or 9 feet before reaching the polished underlying rock, which is a rather felspathic quartz-schist.<sup>1</sup> Where I landed, the rock, smooth and slippery, passes with a gentle slope into the sea.

<sup>1</sup> See Prof. Bonney's determination of this rock, p. 741.

Our boat ran up this rock as over a sand-beach, while both below and above the tide-mark the rock is so grooved with glacial striæ that it looks as if they had been made by the keels of boats hauled over sand which had subsequently indurated, while in reality it is a very hard quartz-schist. This island is girdled in part by a series of old beaches rising one above the other to a height of not less than 100 feet. The highest that I traced looks like a line of ancient fortification. This is due to the accumulation of peat which has spread over it, and which, sloping towards the sea, is on the land-side in many places perpendicular. Where runnels have cut through this terrace the ancient beach is exposed; in it are fragments of nullipores identical with the remains that are piled up along the shore at present sea-level, and these at a little distance look like accumulations of magnified grains of sago. The presence of the remains of this nullipore in the higher terraces effectually disposes of the theory that these beaches might have been the result of interglacial damming.

The remarkable and extensive series of terraces on both sides of the Varanger Fiord, which separates Norway from Russian territory, are well known. My friend Prof. Alfred Newton, who visited the Varanger forty years ago, kindly gave me the following note from his journal and that of Mr. W. H. Hudleston, his companion. They were journeying along the northern side of the fiord, not far from Vadsö. He writes<sup>1</sup>:—‘We continued our walk along a raised beach about 50 feet above high water and 200 yards from the shore, where lay the bones of a whale that had probably been stranded there in old times. Each of the whale’s vertebræ was covered with turf. We scratched the ground in places and found ribs, but I do not remember that we found the head.’

On the little island of Vardö, on which the town is built, and near the fort from which the island takes its name, is a marine sand-deposit some 40 to 50 feet above sea-level. I lately took from this spot remains of seal,<sup>2</sup> cetaceans, fishes, and mollusca. I might easily enlarge the list of localities in Arctic Norway which I have visited, and where similar proofs of recent elevation are to be met with: but I think that I have conclusively shown the presence of marine organisms throughout the raised beaches of Arctic Norway, and consequently their marine origin.

## 2. Terrace-making in Kolguev Island.

On former occasions<sup>3</sup> I have pointed out the part which the ice-foot performs in the formation of terraces in Polar regions. I observed

<sup>1</sup> Alfred Newton, *in litt.* 1895.

<sup>2</sup> Mr. E. T. Newton, F.R.S., F.G.S., very kindly identified these specimens brought from the raised beach at Vardö as belonging to *Halichærus gryphus* (Grey Seal), *Phoca hispida* (Flœ Rat), *Gadus morrhua*, with *Buccinum undatum*, *Modiola modiolus*, and *Pecten islandicus*.

<sup>3</sup> Ann. & Mag. Nat. Hist. ser. 4, vol. xx. (1877) p. 487; Nares, ‘Voy. to Polar Sea,’ 1878, vol. ii. pp. 341-342; Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 565.

the making of a terrace lately on the island of Kolguev, not on a great scale, but still sufficiently important to be a guide. The broken ice-pack was pressed on to the western shore of Kolguev by a strong gale for three days. The width of this pack as I saw it was from  $\frac{1}{2}$  to  $\frac{3}{4}$  mile; it was a chaos of ice-material, blocks and fragments pressed together by the force of the gale which was raging outside, and huge waves dashing over the windward side of the pack. Standing on the beach, the crushing and grinding of the ice-blocks, with their dismal groaning, was audible above the noise of the wind. An 'angry' pack under such circumstances is a very awe-inspiring force of nature. As the ice pressed on the shore, it drove before it banks of mud and gravel; these were pushed up in ridges several feet high, and the tops of these banks were rough and irregular. The gale died away, and the ice, which had

Fig. 2.—Terraces across the mouth of the Gosina River, Kolguev Island.



[From a photograph by H. J. Pearson, 1895.]

acted as a breakwater, disappeared. Then came the influence of the sea. No longer kept back from exerting its power on the shore-line by the protective ice-barrier, the waves at the height of the tide pushed their crests over the heaped-up ridges of mud and gravel, and as they surged along levelled them as flat as a billiard-table. As successive tides came in, not so high or strong as those immediately following the gale, the raised surface was cut parallel to the shore-line as straight and perpendicular as if done by a spade

for considerable lengths,  $\frac{1}{2}$  to 1 mile, according to the nature of the shore.

Now, supposing what I saw happened, as it must often do, in the autumn, at a time of great snow-precipitation, this newly-formed terrace would be strongly protected, and when the sea washed against it would rapidly be turned into ice, for snow absorbs sea-water with marvellous rapidity, and the terrace would be enveloped in a mantle as hard as glacier-ice. Supposing that this occurred accompanied by emergence of the land, we have found here one cause for rapid construction of terraces. That this does happen I have no doubt, for where I saw the terrace made, namely, between the Gosina and Kriva rivers, there were three other terraces standing behind this last-formed one. The oldest of these was apparently above the influence of present high tides, being about 100 yards inland, some 6 feet in depth, and possessing a perfect slope. For most of its extent this terrace was covered by a protecting mantle of *névé*, which was only bared at intervals; but in these places it showed perfectly regular terrace-structure.

### 3. Glacial Geology of the Kola Peninsula.

As we sail eastward along the Murman coast of Russian Lapland, we see on our right hand a bold and precipitous country. Its highest summits appear to rise to 500 or 600 feet. The hills are planed down to a general level, and no peaked mountain breaks the monotony of the scene. In bays and indentations, immense raised beaches are noticeable, especially to the westward of Cape Cherni. Sviatoi Nos is the prominent headland which marks the entrance to the White Sea when approaching from the westward. This promontory forms the eastern side of Sviatonoskaia Bay, and the Ukanskoe River enters its south-western angle. Here the river is about  $\frac{1}{2}$  mile wide and is navigable for vessels of small draught for  $3\frac{1}{2}$  miles, when the rapids commence and the tidal influence ceases. From the entrance of the river to the rapids it is more correctly a fiord, flanked on each side by steep heights of granitic, gneissoid, and dioritic rock,<sup>1</sup> which rise to an elevation of 250 or 300 feet. A remarkable feature in this fiord is a ridge of large boulders which lines either shore to the height of 20 feet or more. It does not seem credible that tidal influence could have ranged the boulders in their present position, although the rise at spring-tides is 14 feet.

These boulders are of the same lithological character as the rocks in the neighbourhood. On ascending to the uplands from the banks of the Ukanskoe, an elevation of some 300 feet, we find a sombre grey, monotonous expanse of ice-worn land with hardly any surface-soil. There are hills, and eminences, and escarpments of rock, with undulations and swellings in this rock-surface, but the highest points are probably not more than 600 feet above sea-level, and 500 feet, measured by aneroid, was the greatest elevation that

<sup>1</sup> See Appendix by Prof. Bonney, p. 742.



Fig. 3.— *View on the Ukanskoe River, Kola Peninsula, showing fringe of erratics skirting the shore.*



[From a photograph by H. J. Pearson, 1895.]

the writer reached. A remarkable and prevailing feature of the country is the vast number of erratic blocks spread over it in every direction. Standing on some eminence we see around us countless boulders, all clad in coats of shaggy lichen, reminding one of Catlin's pictures of herds of bison resting on the prairies of the Far West. But our astonishment is increased when we examine them individually, and see the extraordinary positions that some of them occupy. Here a huge block resting on a couple of others, there two or three raised directly one upon another, again others standing as monoliths. From the descriptions of the distribution of erratics in Finland and Lapland by Durocher, Wraxall, Clarke, and others, I was prepared to see a remarkable number, but their dispersal over this portion of the Kola Peninsula excited my astonishment.

When the eye becomes better acquainted with the position of these blocks, certain salient features appear. Though they are spread generally over the surface of the country and lie broadcast on eminences and slopes, yet there is a tendency for them to collect in hollows and undulations of the surface. A notable feature in these aggregations is the entire absence of earth, clay, or sand between the blocks. As all these boulders are covered with a thick lichen-growth, it is impossible to note whether they are grooved or ice-

Fig. 4.—*General view of the boulder-covered area on the tundra, in the neighbourhood of Sviatoi Nos, Kola Peninsula.*



<sup>c</sup> Fig. 5.—*View of the boulder-covered area in the neighbourhood of the Ukanskoe River, Kola Peninsula.*



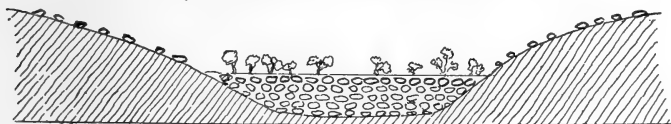
[From photographs by H. J. Pearson, 1895.]

scratched. Fragments which I took from some of them are pronounced, by Prof. Bonney, to be fine-grained reddish granite, moderately coarse, rather felspathic gneissoid granite, a pale red gneissoid rock, granitoid or slightly gneissoid rock, and a dull red very fine-grained felspathic sandstone.

By referring to the valuable and exhaustive appendix of Prof. Bonney (p. 742), it will be seen that these erratics agree so closely in character with the rocks *in situ* of that part of the Kola Peninsula, that there can be little or no doubt as to their local derivation. The accurate determination of these rocks by so high an authority is of great importance. It presents strong evidence that there is no importation of foreign rocks among the vast accumulations of boulders on the Kola Peninsula—that no ice-sheet bearing its cargo of rocks from the north ever passed through Barents Sea, or impinged against the northern coast of Europe. It seems to me that in this local manufacture of erratics on the Kola Peninsula we meet with a striking example of the destructive powers of an ice-sheet resting on a comparatively level area.

Considering the tendency of the erratics on this part of the Kola Peninsula to accumulate in hollows and undulations of the surface, it appears that we have evidence pointing to a somewhat sudden recession or withdrawal of the ice-sheet. I do not accept a diluvial

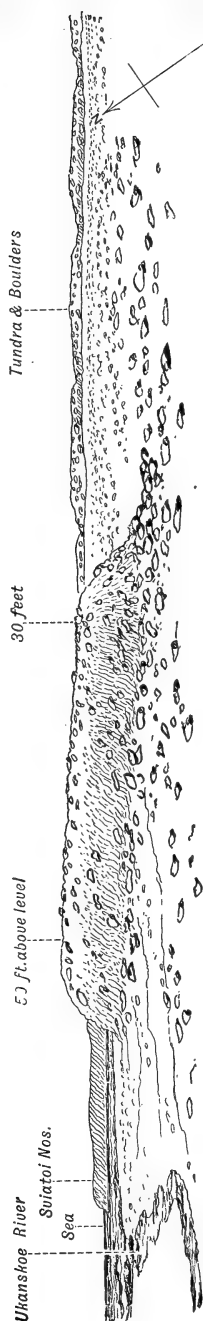
Fig. 6.—*Diagrammatic section of boulders in hollows, neighbourhood of Sviatoi Nos, Kola Peninsula.*



theory, such as a deluge sweeping the erratics into the undulations, but it seems probable that during the melting of the ice-sheet there was a tendency for the decomposing ice to drift the blocks into the hollows as we now see them. On the other hand, for all we know to the contrary, it may be incidental to an ice-sheet moving over a comparatively level land to push the boulders into depressions of the rock-surface beneath it. Only in one spot did I meet with a formation that had somewhat the appearance of a moraine, but as it consisted entirely of blocks, without any sand or smaller *débris* visible, it may be merely an accumulation of blocks formed under the ice-sheet. This mound stood on the edge of a ridge, which looks down towards the valley of the Ukanskoc River: its elevation is 415 feet, and it runs nearly due north and south, is about  $\frac{1}{2}$  mile in length, and about 40 feet in height.

Eastward of the estuary of the Petchora River the great Bolshaia Zemelskija tundra stretches to the base of the Urals, and along it we find proofs of elevation of the land in recent times. The Arctic explorer, Mr. F. G. Jackson, in his book 'The Great Frozen Land' (p. 128), tells us:—'We had been steadily travelling

Fig. 7.—Tundra, with boulders, neighbourhood of Ukanskoe River, Kola Peninsula.



across the frozen tundra for eighteen days, when on the 1st November we crossed the Piatsoworyaha River, and on the following day, about 8 miles west of the river, entered a most interesting region. Right in front, and away to the northward, there spread the amphitheatre of an old bay, whose width would be about 15 miles, and its inmost reach at least 9 miles from the present seashore. Step above step there ranged the old sea-beaches, following the lines of the higher land immediately behind them, and girding with a terraced rampart the level basin of salt marsh into which the waves once rolled. The beaches themselves were now thickly covered with grass, and the grass with snow; but walking along the terraces I found several pools of salt water, and a number of recumbent pine-trees—one of which I measured, to find it was 40 feet long, and 2 feet in diameter at the thickest end.' From this it would appear that we are justified in assuming that the secular elevation of what is now the Bolshaia Zemelskija tundra was coincident with the emergence of the island of Kolguev, with its marine boreal beds now rising to a height of 250 feet above the sea. Further, I think that the cartographers of maximum glaciation in Europe should hesitate before extending an ice-sheet over that wide region lying between the Timan and Ural ranges, north of the Arctic Circle.

In order to connect our survey of the Arctic coast of Europe with the islands of Novaya Zemlya, I will again quote from Mr. F. G. Jackson, who, so far as I am aware, is the only educated person who has traversed the island of Waigatz in its entirety, and his observations are of interest when taken in conjunction with mine on Gooseland in Novaya Zemlya. From Mr. Jackson we learn that there are two main ridges on Waigatz, that on the eastern side composed of limestone and limestone-shale running in a north-west to south-easterly direction, and having a general elevation of from 150 to

300 feet, the other parallel to it on the western side of the island, but not rising higher than 70 feet. The intervening portion and the land bordering the sea he describes as tundra. Mr. Jackson writes<sup>1</sup>:—‘The tundra rolled away to the point, the ridges sometimes reaching a height of 30 feet above the intervening troughs. Along the lowest level of the troughs shallow pools and lakes were frequent . . . . Down in the troughs the soil was bluish mud . . . . while on the ridges there outcropped the long friable sheets of limestone-shale which I found all over the southern part of the island and on the tundra around Habarova. . . . Round Dolga Bay (on the north-western side of the island) there is every evidence of the present shore-line being of comparatively recent existence. A raised beach about 12 feet above present level runs persistently along the cliffs.’

#### 4. Novaya Zemlya.

My personal acquaintance with Novaya Zemlya is limited. I have visited only a small portion of the western side of the south island, between the parallels of 71° and 72° lat. N. The appearance of this part of Novaya Zemlya is disappointing in scenic effects. There is nothing in its character approaching the grandeur of the western coast of Spitsbergen. Making for the shelter of Kostin Schar or Strait, that protected reach of waters lying between Mesdusharsky Island and Novaya Zemlya proper, we pass between low-lying Gooseland and Mesdusharsky. Their topographical features are quite distinct from those of the rest of Novaya Zemlya, and they appear to be long low tracts of tundra just rising above the sea and fringing the interior highlands.

In the vicinity of Rogatcheva Bay, where we made our first landing, the country rises abruptly from the shore to the height of between 500 and 800 feet, more or less. This hilly region, intersected by valleys with many lakes, extends for some 15 to 20 miles to the base of the interior range, which rises in a series of sharply peaked and serrated mountains averaging some 2000 feet in height. At the time of our visit, in the latter part of July, the land was generally clear of snow, little even remaining on the central ridges except in their higher valleys and gorges. I detected no glaciers on their flanks, and we saw no glaciers issuing into Kostin Schar.

The rock-formations of this part of Novaya Zemlya dip at very high angles, often nearly vertical, so that their outcrops appear as ridges. On all sides these are shattered and riven by frost, so that we walk over leagues upon leagues of splintered and shivered rocks. This is the work of frost and subaerial disintegration. I can see no evidence of the former extension of an ice-sheet over this area, no ‘*roches moutonnées*,’ no glaciated surfaces, no rounded, mammillated, ice-worn contours. Had these at any time existed one can hardly suppose that they could have been totally removed by the

<sup>1</sup> *Op. cit.* pp. 31, 32, 37.

action of frost. I am making no reference to stratigraphical geology in this paper, but it may be mentioned that some 5 miles inland from Rogatcheva Bay I came across an outcrop of rock, apparently very similar to a characteristic series of erratics in the glacio-marine beds of Kolguev. It contains plant-remains, and is probably of Jurassic age (see p. 744). It is quite within the range of reasonable assumption that a portion of the Kolguev erratics may have been floated from Novaya Zemlya.

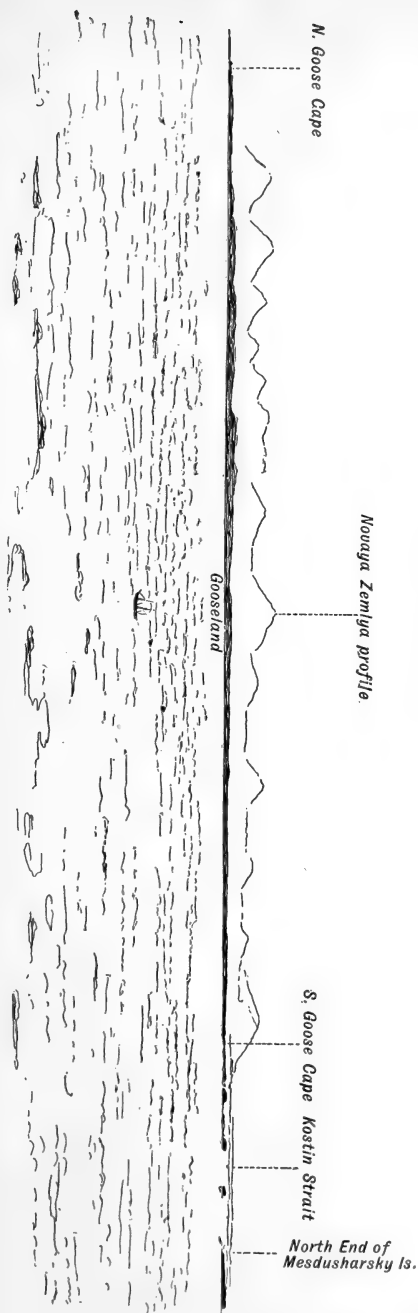
It is to Gooseland and the islands in Kostin Schar that I wish particularly to draw attention. The latter are worn down and abraded in contour, but as the rocks of which they are composed almost always crop out at a high angle, and as they are very shaly in character and readily decay and splinter, no marks of glaciation are left on them. From Prof. Bonney's report they appear to be sedimentary rocks of Palæozoic or Archæan age.

All of these islands which I was enabled to visit have deposits of boulder-clay lying in their undulations and hollows. I met with sections showing a depth of 20 feet; the clay is of the same colour as the rocks upon which it rests, and the included stones are angular fragments of the same rock. I did not detect an erratic, or a rounded stone, or an ice-scratched stone in any of this boulder-clay. In many places it is full of shells of marine mollusca, *Saxicava arctica* predominating, though I found other species common enough. In some localities one might gather these shells by the bushel, few of them broken, never triturated, and in some cases the two valves are in contact.

This description holds good also of the part of Gooseland that I visited, the abraded ridges, the deposits of boulder-clay in the troughs, and the presence of shells of mollusca, all being characteristic features. As I have expressed a very decided opinion that no ice-sheet has ever extended over this part of Novaya Zemlya, I may be asked to account for the presence of these widespread deposits of boulder-clay, with the assemblage of the remains of marine mollusca in them. I venture to urge the view that the wearing down of Gooseland and the islands in Kostin Schar, and the deposition of the boulder-clay, are entirely due to the action of floating ice.

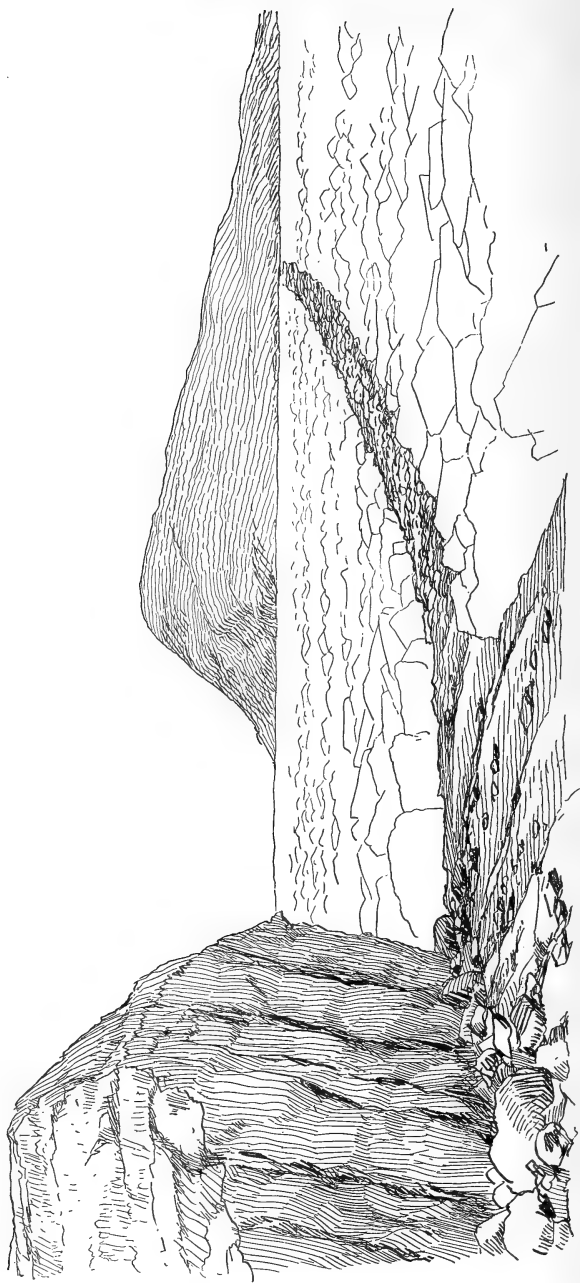
I pass on to give some examples which I witnessed of the force that floating ice can exercise. Last summer I was observing a narrow pack of floating ice which for a few days hemmed in the western side of the island of Kolguev. This ice-pack was moving along the shore at the rate of 3 or 4 miles an hour. Some  $\frac{1}{4}$  mile seaward from the beach on which I stood lay a shoal under water. At this spot there was a constant turmoil and hubbub in the floating ice. The unusually heavy pieces grounded on this shoal, and for a short time checked the march-past of the ice-column. The delay, however, was no long one; the pack accumulated behind, and by its pressure forced the lagging blocks over the shoal. As a rule, the accumulating pack dealt in a very summary way with the obstructionists, by passing under them and turning them upside

Fig. 8.—Sketch of Gooseland, July 4th, 1895.



[We had run through 40 miles of pack-ice, but found it impenetrable and wedged fast on Gooseland for 10 miles, closing Kostin Strait, and belting round Mesdusharsky Island.]

Fig. 9.—*Islands in Koston Schar, connected by a glaciated ridge, or causeway, covered with shingle.*



[The floe is shown pressing up on either side: at the left-hand corner the ice is pushing against the land.]



down on the floe. The undersides of these blocks came up covered with mud and detritus from their contact with the bottom, and were swept onward by the ice-pack, their black colour being very distinguishable on the white surface of the ice-stream. Now, to force these blocks of ice, which were probably 8 to 10 feet in thickness, over an obstacle must require immense pressure, and it seems unreasonable to suppose that they do not exercise some abrading force; if not, why should the blocks have their under surfaces coated with material from the bottom? What I saw occurring at Kolguev on a small scale has doubtless been carried on extensively off the coast of Novaya Zemlya. Given a comparatively flat tract under water, such as Gooseland was, and a constant process of emergence, I see no reason why floating ice moving with a hundredfold greater velocity than a glacier should not be able to wear down ridges over which it passes, provided that the process of secular elevation is bringing the land and the floating ice into contact. The formation of boulder-clay, replete with mollusca, would be the natural sequence.

Next let us turn to a more distant part of the Polar area, where the powers of floating ice are witnessed on a much grander scale. In Smith Sound the fragments of the heavy floes of the Palæocrystic Sea are summer and winter endeavouring to work their way southward. Much of this ice is of stupendous thickness, floes 40, 50, and even 100 feet thick being met with. This vast body of ice, ever moving slowly southward through the strait, pushing over shallows, and rubbing and grinding against the shore, must surely be gifted with some wearing force. At headlands, or where the progress of this pack is interfered with, the enormous power of floating ice is exemplified. At such a point of pressure, the ice pushing against the shore exerts extraordinary force. An enormous mass of floe is brought to a stop against some part of the shore, while the check is transmitted to the ice pushing behind. The edges of these various floes are brought into contact with one another; they rise at their edges and crumble upon themselves, forming ridges of pressed-up hummocks 50 to 60 feet high. The pressure from behind forces the grounded floe to act in a similar manner against the shore. Slowly, as if urged by some hidden hydraulic force, the edge, impinging against the shore, commences to rear itself up in a chaos of ice-débris, and the blocks roll down on the floe or on to the shore. The portion that has grounded or been jammed against the shore being now pulverized, the obstruction is cleared, and the ice resumes its onward march. Is it possible that such pressure between land and floating ice can take place without some effects being produced? I think not, for at such points of contact, when we were able to reach them, we found the rock polished.

There are two or three islands lying along the eastern shore of Grinnell Land in Smith Sound, which offer some useful testimony, notably Norman Lockyer Island, which is encircled by several well-defined terraces or sea-beaches to an altitude of 300 feet. These terraces rest on rock-surfaces which show in places, where they are

laid bare, ice-worn surfaces and striations. Now, as the striæ on the limestone-rock of this island are as fresh-looking as if they had just been made, I am at a loss to understand how this can be, if they are due to the effects of land-ice. If so, how great the changes which these striæ must have encountered! First, what is now the water-way of Smith Sound must have been occupied by land-ice, then it must have disappeared, and the land must have sunk sufficiently at least to allow of the highest terrace being formed, which would be a submergence of 300 feet. Then followed a period of emergence, during all which time the island has been undergoing contact with floating ice, and yet we are asked to believe that the scratchings of the former ice-sheet have remained on the rock as fresh as they appear on the specimen that I have now in my hand! It seems more likely that the glaciation and striation went on simultaneously with the emergence of the island from the sea, and that they are the result of floating ice pushing over or along the island.

In Kostin Schar many of the islands and islets are connected by ridges, and frequently one is able to walk from one island to another over a causeway  $\frac{1}{2}$  mile, more or less, in length. These causeways are covered with rounded stones and shingle, the pushed-up floe-ice lying on either side like the pictures of the 'passage through the Red Sea' in the books of our childhood. If we examine such a causeway we find that it has no character in common with a moraine, for the shingle is rounded by the action of the sea, and is only a few feet in thickness at the most, while in spots where the shingle does not lie the glaciated surface-rock appears. Now, when we reach the end of a causeway and the base of either of the connected islands, we not unfrequently find the floe-ice pushing up the ridge and against the base of the island in a way that shows it to have a scarping and destructive force. (See fig. 9, p. 734.) We can point as evidence of this to the pieces of rock and débris which have recently fallen from the escarpment of the island on to the ice-floe, and to disjointed pieces of rock ready to come away which are to be noticed at the meeting of the impinging ice and the abruptly rising land-face. Moreover, as I have already remarked, the surface of the ridge on which the edge or snout of the floe-ice is pushed up is glaciated.

I have seen similar glaciated, shingle-strewed ridges appearing above the sea, with the pack-ice grounded and pushed up on either side, in many other parts of the Arctic regions—Spitsbergen, for instance. I have in my possession a photograph of a well-marked ridge in Loom Bay, Spitsbergen (taken during Mr. B. Leigh Smith's voyage to that country in 1873), which that distinguished Arctic explorer gave me on his return. Being desirous of learning whether the views of that highly qualified observer coincided with my own, I recently communicated with him and received the following reply:—'I believe that the ridge in Loom Bay, Spitsbergen, of which you send me a sketch, was formed by the ice grounding on each side of a shallow, and forcing up the shingle from the bottom. There is a strong tide running into and out of Loom Bay. In Hinlopen Straits

there are many low islands of columnar basalt which have been polished by the ice driving over them. I do not recollect whether the ends of these islands had been worn away or whether they were connected by ridges.'

I have observed several minor phenomena connected with glacial geology in Novaya Zemlya on which I should like to make some remarks. There is a peculiar phase of rock-erosion which a photograph shows better than any words can explain. The large lake

Fig. 10.—*View on the Neckwatowa River, Novaya Zemlya, where it issues from Wilczek Lake (showing rock-erosion).*



[From a photograph by H. J. Pearson, 1895.]

of Neckwatowa, which is on the western side of Novaya Zemlya in lat.  $71^{\circ} 20' N.$ , communicates with the sea by a passage that has been cut through hard limestone-rocks thrown up almost vertically. The fossils in these are so badly preserved that it is not possible to indicate their precise age. (In connexion with this will be found a report by Mr. E. T. Newton, F.R.S., in Prof. Bonney's Appendix.) This channel is about a mile in length, and from 80 to 100 yards in width; the walls on either side are precipitous, and their height is 40 to 50 feet. There can be little doubt that the channel has been cut out by the water and ice passing from Neckwatowa Lake to the sea. (See fig. 10.) It will be noticed in the photograph that

on both sides of this channel at the present water-line the rock is eaten away in the shape of a semi-culvert. This is largely due, I imagine, to ice-abrasion; but at the same time does it not point to a lull in the upward movement of the earth in this part of Novaya Zemlya?

A phenomenon observable in all Arctic regions, whence the snow dissolves in summer, has not, I think, received adequate explanation. It is that tendency of the surface-stones to arrange themselves most commonly in the form of hexagons. We see this on a small scale on Scottish mountains, and very commonly in Iceland. Pajkull refers to its occurrence in Iceland, and gives a sketch<sup>1</sup> illustrating this disposition of the stones on an Icelandic 'Melr.' His explanation is not altogether satisfactory, though it is founded upon that of so high an authority as Prof. Steenstrup, namely, that the earth rendered soft by the melting of the snow in spring has become dried by the heat of summer; that rifts or cracks are formed in it, and when a storm occurs the small stones that lie on the surface of the 'Melr' are swept down into them. This explanation does not, however, account for their formation on the large scale met with in high Arctic latitudes. I have seen in Novaya Zemlya these arrangements of stones occurring in groups, the diameter across each enclosure being 18 inches to 2 feet—the stones composing the enclosures being of considerable size, a foot or more square; the interior was occupied by a mound resembling a mole-hill. I think that the arrangement is unquestionably connected with the melting of the snow, but why the stones should be distributed as they are is not quite clear.

To another phenomenon that we observed on Gooseland we gave the name of 'stone-bogs.' Tracts of soft mud, in which a man sinks over the boot when walking, were frequently covered thickly with stones, so much so that we could walk in comfort over these treacherous spots for a hundred yards at a stretch. The stones moved under the tread, but did not sink. They lay on the surface of the quaking mud as smoothly as if a roller had been passed over them.

## 5. Franz Josef Land.

We have evidence that secular elevation of the land is as recognizable a feature in Franz Josef Land as in other parts of the Polar area. Payer frequently mentions the raised beaches, visible on all sides, during his sledge journey up Austria Sound,<sup>2</sup> while the members of the Jackson-Harmsworth Expedition report that their winter house 'is situated on a raised beach 115 feet above the sea.'<sup>3</sup>

<sup>1</sup> 'A Summer in Iceland,' p. 21, Eng. trans., London, 1868.

<sup>2</sup> 'New Lands within the Arctic Circle.'

<sup>3</sup> Montefiore, Geogr. Journ. vol. vi. (1895) p. 507.

## 6. Spitsbergen.

Spitsbergen, especially its western coast, presents the most sublime and magnificent scenery that I have met with in Polar lands. Its western shore is as easy of approach in summer as that of Norway, and secure anchorages and harbours can always be reached. It is a land pre-eminently suitable for the study of glacial effects, for not only do we find there the forces of land-ice, but also, as it is an area of rapid emergence, the phenomena connected with glacio-marine action can be seen in progress. Along the shores of the great estuaries, such as Ice Fiord, old sea-beaches and terraces, containing the shells of recent mollusca in great quantities, are frequent. But the only novel observation which I have to record is that, owing to the rapid elevation of the land, we can examine in detail immense deposits originally formed under water in front of glaciers. These deposits in many cases now lie between the present shore-line and the edge of the glacier of to-day, and their thickness and extent make them deserving of attention. A very notable formation of this nature is to be found at the head of Green Harbour, one of the minor indentations on the southern side of Ice Fiord. The front of the glacier that now occupies the valley is about a mile distant from the present shore-line. Fronting this glacier, the terminal face of which is about 50 feet in height, and extending entirely across it for  $1\frac{1}{2}$  mile in length, is a range of low hills, some 50 to 70 feet high and  $\frac{1}{2}$  mile in width. These hills have undergone much subaerial erosion, and channels have been cut in them by the numerous streams issuing from under the glacier. Following up one of these watercourses, which average from 25 to 50 yards across, with a very level bottom, we find sections of mud and clay, rising like walls on either side to

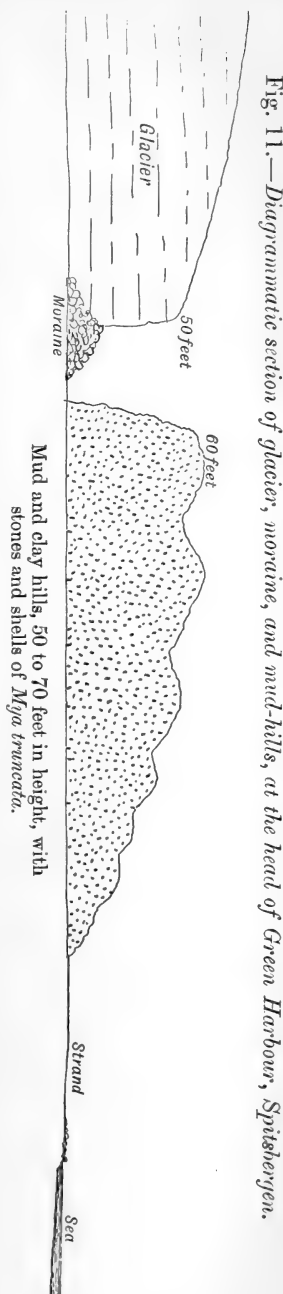


Fig. 11.—Diagrammatic section of glacier, moraine, and mud-hills, at the head of Green Harbour, Spitsbergen.

a height of from 50 to 60 feet. These beds contain numerous stones, but neither they nor the stones themselves show any sign of stratification; in them I found shells of *Mya truncata*, but in no great quantity. That these beds are of submarine formation is confirmed by the existence of raised beaches in the neighbouring fiords, and along the adjacent line of coast, at a higher elevation than the beds which I am describing. Between the present face of the glacier and the perpendicular wall of the mud-hills runs a sort of ditch, dry moat, or open space some 30 yards in width, along the entire front of the glacier. The bottom of this ditch or moat is thickly strewn with morainic debris composed of rounded ice-worn stones, many being deeply grooved, scarred, and scratched. Through this slope of rocks and stones the glacier-streams were pouring forth when I visited the spot in July 1894.

If the glacier, as it now does, can force this immense quantity of rounded and scratched stones from beneath it, the same process must have been going on when its snout was submerged in the sea. It seems to me that when emergence of the land is proceeding, as it is now in Spitsbergen, there must come a period when the water at the face of the glacier shoals sufficiently to allow of the bay-ice which forms throughout the winter freezing deep enough to incorporate the boulders of the moraine. This being so, quantities of ice-scratched and ice-polished boulders, stones, and pebbles must be floated away on the breaking up of the bay-ice in summer. This would be a simple explanation of the occurrence of the vast number of scratched erratics which are to be found in the glacio-marine beds of Kolguev Island.

It is well known, and has frequently been remarked by travellers in Greenland, that in the neighbourhood of many of the glaciers discharging into the sea the water is discoloured with sediment, and contains a large quantity of suspended material. That this matter must in time be precipitated is evident; and when lifting the ship's anchor from the front of some of these glaciers (notably the Tyndall Glacier in Bardin Bay on the north-western side of Greenland) I have seen it come up with many pounds' weight of unctuous mud intermixed with sea-shells adhering to the flukes. It is therefore quite evident that water issuing from under a glacier in the Polar regions, and discharging from under the ice into the sea, can lay down glacio-marine beds in the ocean, and that the occurrence of ice-scratched stones throughout these beds can be accounted for.

My object has been to set forth in this paper the effects of glacio-marine action in the alteration of coast-lines, the deposition of boulder-clays, and the glaciation and polishing of rocks by floating ice. I have not alluded to the glacio-terrene geology of the Far North, as it would have extended this paper to unreasonable limits. I have endeavoured to avoid theories and hypotheses, and have confined myself to a bare narration of facts as I have observed them and as I understand them. Do not suppose that for an instant

I compare the glacial effects of a continental ice-sheet as we find it now in Greenland, or as it formerly existed over a large portion of Europe and North America, with glacio-marine action; but undoubtedly the latter has been and still is a not unimportant factor in glacial geology.

In conclusion, I beg to thank Prof. Bonney for his kindness in adding two valuable appendices to this and my former paper. His examination and description of these rocks, some of them from remote and inaccessible localities, are valuable in themselves; but I am most grateful for the light which they throw on the origin of some of the erratics that I have met with.

There can be no doubt that many of the erratics found in the glacio-marine beds of Kolguev are of precisely the same lithological character as rocks found in place in Novaya Zemlya, and we may presume with great confidence that they were carried thence by floating ice and dropped to the bottom in that part of Barents Sea which has now risen into dry land. Again, it is extremely interesting to find, from Prof. Bonney's investigation, that the vast accumulations of boulders on the Kola Peninsula are derived from local rocks, without, so far as we know, any foreign admixture.

#### APPENDIX.

REPORT on SPECIMENS COLLECTED by Col. H. W. FEILDEN in ARCTIC NORWAY, etc. By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., V.P.G.S.

In the following notes the specimens collected by Col. Feilden are grouped according to localities and arranged in the order of the dates on the labels.<sup>1</sup>

##### (i) FROM ROCK IN PLACE, STOR TAMSÖ, PORSANGER FIORD, NORWAY.

(28.) A fine-grained, faintly speckled, light grey rock, apparently either a quartzose gneiss or quartz-schist, without strongly marked foliation. On examining a slice, quartz proves to be the dominant mineral. It occurs in rather elongated irregularly-outlined grains, with borders of a different tint (with crossed nicols). A dark olive-brown biotite is present in both fair-sized flakes and tiny flakelets, with some felspar, but much less than one would expect from the macroscopic aspect of the rock; there are also a few small garnets, a little iron-oxide, and zircon. Macroscopically and microscopically the rock reminds me of some quartz-schists which I have collected near Braemar, Aberdeenshire, and in the neighbourhood of Clifden, Connemara.

<sup>1</sup> The numbers are those affixed to the specimens by Col. Feilden. Sections were prepared for the microscope in cases where the rock seemed likely to be specially interesting. In other cases a fragment was powdered, and the material was mounted on a slide and examined.

(ii) BOULDERS FROM TUNDRA IN THE NEIGHBOURHOOD OF  
SVIATOI NOS, KOLA PENINSULA.

(29.) A fine-grained reddish granite, rather rich in felspar and poor in mica (biotite and a little muscovite). Examination of the powder shows that some of the felspar is ferrite-stained, that microcline is present, and that the iron oxide probably is hæmatite.

(19, at Sviatoi Nos.) A moderately coarse, rather felspathic, reddish-coloured gneissoid granite; the biotite (not very abundant) exhibits a slightly linear arrangement. A good deal of muscovite is seen on close examination with a lens; this also is found in the powder, together with biotite and a very light brown mica, as well as plagioclastic felspar and microcline. The outer surface of the fragment has assumed in weathering a peculiar, rather lumpy, slightly glazed aspect. Possibly it may be part of a vein.

(8.) A dullish red (slightly mottled) very fine-grained felspathic sandstone, with a few specks of mica, bearing some resemblance to Torridon Sandstone, but with smaller grains than is usual in that rock. Examination of the powder shows the quartz-fragments to be angular in form and somewhat ferrite-stained, with plagioclase and microcline among the felspar, also a tiny chip of garnet.

(24.) A whole stone, labelled 'miniature boulder,' about  $3'' \times 1.75'' \times 2.25''$ , rudely oblong, slightly tapering at one end. This appears to be a granitoid or slightly gneissoid rock.

(26.) An ovoid pebble, rather blunted at one end, of moderately coarse, pale-red gneissoid rock.

(16.) A fine-grained dioritic rock with a very slight approach to a foliated structure—felspar light-coloured, hornblende dark. Examination of a slice shows the following minerals:—(a) Green hornblende, strongly dichroic, with occasional inclusions (see 22, p. 743) in irregularly-shaped grains; (b) biotite in fairly idiomorphic flakes, often in close association with the hornblende, as if formed at its expense; (c) felspar—in quantity about one-half of the rock—in irregularly-shaped grains, being often moulded on the mica; occasionally slightly decomposed, much of it plagioclase, with both albite- and pericline-types of twinning. Sometimes a grain, which with ordinary light appears single, is found on applying the nicols to be composite. A few grains of quartz, granules of iron oxide, and several microliths of apatite also occur. The structure is peculiar: it may be the result of dynamic action, but there is nothing to prove this; possibly it is due to a partial fusion anterior to final consolidation, by which biotite has been produced at the expense of original hornblendic and of felspathic constituents.

(iii) ROCKS IN PLACE, FIORD OF UKANSKOE RIVER,  
KOLA PENINSULA.

(20—At edge of water close to camp, June 24th.) A rather coarse gneissoid rock, with some approach to a banded order in its constituents—like Archæan specimens from Greenland and Norway.



Quartz, feldspar, and biotite are readily seen. The powder shows the feldspar (orthoclase probably predominating) to be rather full of minute enclosures; also very dark-coloured biotite, with some white mica, a little garnet, and (?) epidote.

(12—June 26th.) A rather coarsely crystalline, reddish granitoid rock, with much feldspar. A slice shows the following minerals:—(a) quartz, in grains of moderate size and irregular outline, generally composite; in it hair-like microliths and small fluid cavities with bubbles are rather frequent. (b) Feldspar in grains variable in size and interrupted by inclusions. Microcline is common, but the other grains, as a rule, show no signs of twinning. Occasionally they are rather decomposed, and contain many flakelets of colourless mica irregularly disposed. Also in parts towards the outside they seem to break up into a mosaic of granular feldspar, with an occasional trace of micropegmatitic structure. The inclusions mentioned above are sometimes quartz, sometimes feldspar, the latter seemingly a different variety. (c) A ferro-magnesian mineral, irregular in outline, inclined to be opaque, which in most, if not in all cases, is biotite. A small quantity of a light-coloured mica, which not improbably is a bleached biotite, also occurs. (d) In one part of the slice two or three small patches of a more decomposed mineral, intercrystallized with the feldspar, suggest the possibility that a little *elæolite* may be present. There is a little apatite and *hæmatite*, and a grain or two of a colourless mineral, possibly *andalusite*. The mosaic structure in the quartz and the feldspar is not improbably the result of some secondary change, perhaps due to pressure, but not to actual crushing. From the general appearance of this rock I should infer that it is of Archæan age.

(21.) A moderately coarse, rather feldspathic granite. The powder shows quartz, feldspar (orthoclase, microcline, and a little plagioclase), two kinds of mica, one being a dark biotite, the other (in small amount) having a very light-brown colour.

(22.) A fine-grained dioritic rock—feldspar nearly white, hornblende (abundant) nearly black. Examination of a slice shows that rather more than half the rock consists of a rich green hornblende, which is strongly pleochroic, irregular in outline, including occasionally grains of water-clear feldspar, iron oxide, and (?) sphene. Small cylindrical or plate-like inclusions of a dark brown colour also are frequent, like those common in diallage, hypersthene, etc., arranged parallel with the planes of  $\infty$  P. The intervals between the hornblende are occupied by small, rather irregularly-shaped grains of feldspar, often water-clear (possibly in some cases quartz), together with a nearly colourless epidote. Both the hand-specimen and the slice exhibit a slight approach to foliation. A considerable amount of secondary mineral arrangement is suggested by the structure of the rock, but there is no definite evidence that this has been the direct result of pressure.

## (iv) NOVAYA ZEMLYA.

(18—Vicinity of Rogatcheva Bay, July 17th, 1895.) A very fine-grained, rather felspathic sandstone, of an olive-grey colour, somewhat carbonaceous and containing plant-remains, very like those specimens from Kolguev Island described in a former paper (*antea*, p. 61). The powder shows quartz, angular chips of felspar (no evidence as to species), two or three flakes of mica (white and brown), and a grain of tourmaline.

Mr. A. C. Seward, M.A., F.G.S., who examined similar rock-specimens from Kolguev Island, has kindly furnished a note on this one. He states that 'the broader fragment (of a plant) may be a fern-rachis, but any trustworthy determination is impossible. The smaller needle-like fragments suggest either *Pinus*-leaves or, perhaps more probably, leaves of *Czekanowskiana*, a fairly common Jurassic genus. Heer and others have described various species of the latter from Arctic plant-beds. The appearance of the rock and the fossils reminds me somewhat of specimens from Spitsbergen and Greenland which I recently saw in the Stockholm Museum, but my recollection of them is much too imperfect to be cited as evidence. On the whole, however, a Jurassic age seems to me the most probable.'

(9—Basement-rock, Kostin Schar, July 17th.) A rather hard, very fine-grained sandstone, exhibiting well-marked current-bedding. The powder shows quartz, felspar, two kinds of mica, one grain which is probably tourmaline, and two zircons, slightly smoke-coloured.

(7—Kostin Schar, July 17th.) A dark greenish-coloured rock, the surfaces of which, though weather-stained, in places suggest a clastic structure. Examination of a slice shows the rock to consist of fragments, the interspaces being filled up by a carbonate (often calcite, possibly sometimes dolomitic). This is occasionally spotted with small flecks which polarize with varying intensity, and probably represent dust from the larger fragments. These fragments are both rocks and separate minerals. Of the former the majority result from the hydration of a basic glass, and the material may be now designated 'palagonite.' One of them exhibits a series of parallel wavy lines, like a fluxion-structure, sometimes (but not always) parallel with the exterior. The bands are composed of a minute green fibrous or platy mineral, the orientation of which is not always uniform. Its pleochroism is weak, its double refraction is feeble, and its extinction is oblique, but at a rather small angle; the mineral may be clinocllore. It also occupies what appear to have been small cavities in the rock. Embedded in the mass are small crystalline grains, often clustered, of a very pale brownish-buff mineral, with a rather granular surface, fairly high refraction, but not rich polarization-tints; their general aspect suggests a ferrous carbonate. One small fragment (with a few cavities) is full of minute lath-like felspars (the extinction-angle agreeing best with that of oligoclase), and resembles an andesite; another one is

generally similar in structure, but the crystallites are even less distinct. Several 'earthy' scoriaceous fragments occur; others, which are minutely granular in structure and of a brown or dark colour, may represent a sedimentary rock (varieties of indurated gritty mud). Among the mineral fragments are chips of quartz, often angular, retaining sometimes traces of a crystal-face, but occasionally augmented by secondary deposit. Hæmatite is present, also (rather numerous) minute crystals of a brownish tint, with high refraction and rich polarization-colours, probably zircon. The vesicles in the fragments are filled either by the carbonate already mentioned, or (much more rarely) by a zeolite, which bears some resemblance to heulandite. It is impossible to say whether this interesting rock is a volcanic ash, or is mainly composed of volcanic material transported from no great distance; but I incline to the latter view. From its general aspect I should conjecture its age to be either early Palæozoic or very late Archæan.

(2, 3, 4—Island in Kostin Schar, July 19th.) Dull grey, fine-grained, sedimentary rocks, consisting, probably, of quartz and more or less decomposed felspar, with a few flakelets of white mica. They are rather fissile, and in (2) the structure has the appearance of a true but imperfect cleavage. This specimen contains a few specks of pyrite.

(v) NECKWATOWA LAKE AND RIVER, LAT. 71° 20' N.

These rocks are fossiliferous limestones, and they were accordingly submitted to Mr. E. T. Newton, F.R.S., who kindly examined those from Kolguev Island, and has favoured us with the remarks quoted below.

5, 17, 27 are from Maltzan Island in Neckwatowa Lake (July 20th). 'They seem to be portions of the same rock. Upon their weathered surfaces are rod-like bodies, 1 to 2 millimetres in diameter, the longest of which measures perhaps 15 millim. This rock is so crystalline that microscopic sections fail to reveal any definite structure in these rods, although some exhibit indistinct radiating lines and others rather resemble *Amphipora*.'

The other specimens, seven in number, are from the banks of the Neckwatowa River (July 22nd). '(10, 11, 14) contain portions of corals which, on account of their short septa, are thought to be *Amplexus* or some allied form. (25) includes a portion of a turbinate coral, a *Rhynchonella*, possibly an *Athyris* or *Spirifera*, and what looks like a fragment of a crinoid stem, having four divisions in the central aperture. (This specimen and No. 11 are labelled Iron Gate.) (6) shows indications of a coral, and perhaps also of a brachiopod; (31) contains remains of a coral; (13) includes a fragment of a stromatoporoid, possibly *Idiostroma* or *Amphipora*.'

## (vi) ROCK OF LOOM ISLAND IN KOSTIN SCHAR.

(23—July 23rd.) The specimen bears a general resemblance to Nos. 2, 3 & 4, but it is a little more compact and darker coloured. It exhibits a slight fissility, but whether this be a true cleavage is doubtful. Some very faint markings on the surface may possibly be traces of an organism (? vegetable).

## (vii) SOUTH GOOSELAND, NOVAYA ZEMLYA, VICINITY OF BELOOTCHA BAY.

(1—July 24th.) A darkish, rather more carbonaceous rock than the last one, rudely fissile, as one may judge from the form of the specimen, which evidently was a loose flake.

(15—same date.) Another natural flake of a rock generally similar to the last, but darker in colour and rather more fine-grained.

(30—same date.) A similar rock, but still darker and more fine-grained.

These rocks (including 23) are not unlike some of the flaky or imperfectly slaty Palæozoic mudstones.

The collection indicates the presence of Archæan, Palæozoic (later and possibly earlier), and some Mesozoic rocks in the region visited by Col. Feilden. The sandstone with plant-remains appears to be identical with that from erratics in Kolguev Island. The fossiliferous Palæozoic limestone (though unfortunately its organisms are in worse preservation) bears a general resemblance to some of the specimens from that island, and the same may be said of certain of the crystalline rocks of Archæan aspect. Thus the Kolguev erratics may have come from Novaya Zemlya, including the adjacent islands.

## DISCUSSION.

The PRESIDENT congratulated the Author on the very interesting facts which he had brought before the Society. His observations made on the spot were a warning to those of us in the South who were inclined to theorize about an universal ice-sheet. The Author's observations seemed to agree in a remarkable manner with those made by the Canadian geologists, and he would call upon Sir W. Dawson for an expression of his views and of those formed by the Canadian Surveyors.

Sir WILLIAM DAWSON remarked that, as a Canadian, he had listened with especial pleasure to the interesting paper of Col. Feilden, since the raised beaches with marine shells which had been described were very similar to those on the Lower St. Lawrence, as were also the fossiliferous boulder-clays and their contained stones with bases of acorn-shells and patches of polyzoa. The effects of floating ice as described by Col. Feilden were also similar to those observed in the estuary of the St. Lawrence and on the coasts of Labrador and

Newfoundland. The whole of the facts were tending to the conclusion, that instead of ascribing the phenomena of the Glacial Age to continental ice-sheets, we should have to be content with local glaciers on the higher lands and cold ocean-currents pervading the submerged lower levels. Evidently the phenomena could not be explained without giving attention to the evidence of continental submergence, afforded by the clays containing marine remains and the ancient shore-lines found at very high elevations. The action of shore- and field-ice during periods of gradual subsidence and elevation could alone account for the great beds of boulder-clay holding marine shells and tests of modern foraminifera, and the term 'unstratified till' was not always appropriate, as where long-continuous sections could be observed, successive beds were often marked by colour-lines, by rows of stones or boulders, or by fossiliferous layers.

Mr. MARR congratulated the Society on having heard this excellent paper. He was particularly interested to learn that deposits whose marine origin was so ably advocated by the Author displayed no signs of stratification.

The AUTHOR replied, thanking the Fellows for the reception accorded to his paper.

41. *On the PLIOCENE DEPOSITS of HOLLAND and their RELATION to the ENGLISH and BELGIAN CRAGS, with a SUGGESTION for the ESTABLISHMENT of a NEW ZONE, 'AMSTELIEN,' and some REMARKS on the GEOGRAPHICAL CONDITIONS of the PLIOCENE EPOCH in NORTHERN EUROPE.* By F. W. HARMER, Esq., F.G.S. (Read May 27th, 1896.)

[PLATES XXXIV. & XXXV.—MAPS.]

## I. INTRODUCTION.

WHILE engaged in the study of the conditions under which the English Crag-beds were deposited, I was fortunate enough to receive from Dr. J. Lorié, of Utrecht, two important papers on the strata met with in some deep borings in different parts of Holland.<sup>1</sup> These borings reveal the remarkable fact that the Newer Pliocene beds which underlie that country not only attain the great thickness of nearly 500 feet, but have been depressed at one point more than 1000 feet below their original position. The enquiry suggested itself whether this subsidence was connected with the series of earth-movements by which the Older Pliocene deposits of the South of England, of the North-east of France, and of Belgium have been raised to a height of between 500 and 600 feet above the level of the sea, how far the influence of these disturbances could be traced in East Anglia, and in what manner the deposition of the Crag-deposits was affected by them.

The facts I have now to submit show that these movements of upheaval and subsidence have this in common, that they were not confined to one period, but went on, though not continuously, from the Pliocene until late in the Pleistocene epoch. The central portion of the area has not been affected by them to any large extent, and seems to have formed the pivot of the disturbance, while depression has increased progressively in a northerly direction, and elevation has been greatest in the south. For the most part, each of these movements has operated in the direction which it first assumed, with a decided interruption, however, at the end of the Pliocene period, and it will be seen by the section (fig. 4, p. 761) that the total rise of the bed of the Pliocene sea, on the one hand, corresponds, though not exactly, with the greatest depth to which it has sunk on the other. The maximum disturbance, so far as the evidence goes, seems to have been along a line running S.W., and N.E. from the Straits of Dover to the coast of Holland. The East Anglian area has been affected, though not to so great an extent, and I think it will be seen that these movements have had an important influence on the deposition and distribution of the English Crag-beds.

<sup>1</sup> 'Contributions à la Géologie des Pays-Bas, No. 1,' extr. des Archives du Musée Teyler, ser. ii. vol. ii. (1885) Haarlem; do. No. 4, Bull. Soc. Belge Géol. vol. iii. (1889).

The attention of English geologists was drawn to Dr. Lorié's researches by Mr. C. Reid, in 1886,<sup>1</sup> and that gentleman has since dealt with the subject incidentally in his admirable work on the 'Pliocene Deposits of Britain';<sup>2</sup> but I do not think that these discoveries, the most important that have been made for many years in Pliocene geology, have received the attention which they deserve, and I offer no apology for further alluding to them at some length, especially as I believe that they furnish a clue to guide us in working out some of our own problems. My apologies are indeed due to Dr. Lorié (whose courtesy in placing all his material at my disposal I gladly acknowledge), in that I have ventured to differ from some of the conclusions which he has reached.

The consideration of this subject led me to review the work in which, for nearly twenty years, I was engaged in co-operation with my lamented friend the late S. V. Wood, Jun. This work was wholly interrupted by his death in 1884, and until a few months ago no opportunity presented itself to me for resuming it. I desire in this paper, in the first place, to point out a few cases in which I am now disposed to modify the opinions which we formerly expressed, and wherein I still differ from the views of other geologists. I shall, secondly, endeavour to show that a great part of the beds met with in the subsoil of Holland are considerably newer than the Scaldisien of Belgium, to which they are usually referred; and lastly, by grouping together the different facts which bear on the question, I shall attempt to sketch out a rough but continuous outline of the history of the Anglo-Dutch basin during the newer Pliocene period. For this purpose it will be necessary to refer from time to time to the work of other observers, but I will do so as briefly as possible.

## II. CORRELATION OF THE ENGLISH AND THE DUTCH AND BELGIAN CRAGS.

In the opinion of Sir Joseph Prestwich, the sea of the Coralline Crag may have attained a depth of from 500 to 1000 feet,<sup>3</sup> but Mr. Wood and I always thought this estimate excessive. From considerations which I hope hereafter to lay before this Society, it appears to me that our suggestion of from 250 to 300 feet may still have been somewhat too high. However this may be, it is clear that an elevation of the Suffolk area took place after the accumulation of the Coralline Crag, since the upper beds of the Red Crag, deposited in shallow water, are bedded against it, and sometimes at a lower level. The upheaval of the Pliocene sea-bottom has been much greater in the South of England. At Lenham, in Kent, fossiliferous beds, approximately of the age of the Coralline Crag, occupy

<sup>1</sup> 'Nature,' vol. xxxiv. p. 341. Mr. Reid points out in this article the connexion between the elevation of the Weald and the depression which has affected the Diestien beds found in the Utrecht boring. As to the upheaval of the southern and the subsidence of the northern part of the English Crag area, see S. V. Wood, Jun., Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 458.

<sup>2</sup> Mem. Geol. Surv. 1890.

<sup>3</sup> Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 135.

a level, according to Mr. Reid, of about 600 feet above the sea.<sup>1</sup> This elevation, thus increasing to the south or south-west, was accompanied by a subsidence of the northern, or rather of the north-eastern, portion of the East Anglian area. Sir Joseph Prestwich found the base of the Crag at Sutton, where it rests on the London Clay, to be at one place 8 feet, and at another 20 feet above the high-water mark of the estuary of the River Deben.<sup>2</sup> Mr. Whitaker has given the results obtained in three borings near Orford, about 8 miles to the N.E. of Sutton, in two of which it was reached at 26 feet below Ordnance-datum, and in the third at a less depth.<sup>3</sup> At Aldeburgh, 5 miles farther to the N.E., I bored last autumn into the Crag 20 feet below the water-line, without reaching the London Clay, and I was informed that former borings had been carried down 30 feet with a similar want of success.<sup>4</sup> Farther north, at Saxmundham, the junction of the Crag with the Eocene beds is said by Mr. W. H. Dalton to occur at a depth of 60 feet,<sup>5</sup> and at Southwold, 11 miles N.E. of Saxmundham, at about 140 feet below the sea-level.<sup>6</sup> (See section, fig. 1, p. 751).

It has been stated that in a boring in the harbour at Lowestoft the Chalk was met with, 80 feet below high-water mark. If this be correct, there exists under that town a submarine ridge rising through both the Eocene and the Pliocene beds,<sup>7</sup> but at Yarmouth, 40 miles N.N.E. of Sutton, the bottom of the Pliocene basin occupies nearly its normal position, the surface of the London Clay being there found at a depth of 150 feet below the sea-level.<sup>8</sup>

If the Crag beds are present under Yarmouth, as seems not improbable, there is a difference in the level of the base of these deposits of 180 feet in about 40 miles. The section (fig. 1) will show that, although the surface of the Chalk along this line is exceedingly irregular, the base of the Crag dips northward in a fairly uniform manner.

The section (fig. 2, p. 753) from Norwich to Yarmouth shows that the Pliocene beds dip similarly from W. to E. Near the Cavalry Barracks at Norwich, the Crag sands rest on the Chalk at about 45 feet above the River Wensum. At Bramerton, 4 miles to the E.S.E., they are but little above the water-level, while beyond that place they dip below it. The line of junction of the Chalk

<sup>1</sup> *Op. cit.* p. 45.

<sup>2</sup> *Op. cit.* p. 116.

<sup>3</sup> Dalton & Whitaker, *Mem. Geol. Surv. Aldeburgh*, 1886, p. 53.

<sup>4</sup> Sir Joseph Prestwich (*Quart. Journ. Geol. Soc. vol. xxvii.* 1871, p. 496, pl. xx.) shows in one of his sections the junction of the Coralline Crag and the London Clay at Aldeburgh as considerably above O.D., but this is inaccurate.

<sup>5</sup> Dalton & Whitaker, *Mem. Geol. Surv. Aldeburgh*, 1886, p. 53. Mr. Whitaker gives, on hearsay evidence (p. 52), a depth of 130 feet below Ordnance-datum for the base of the Crag at Leiston, but is this correct?

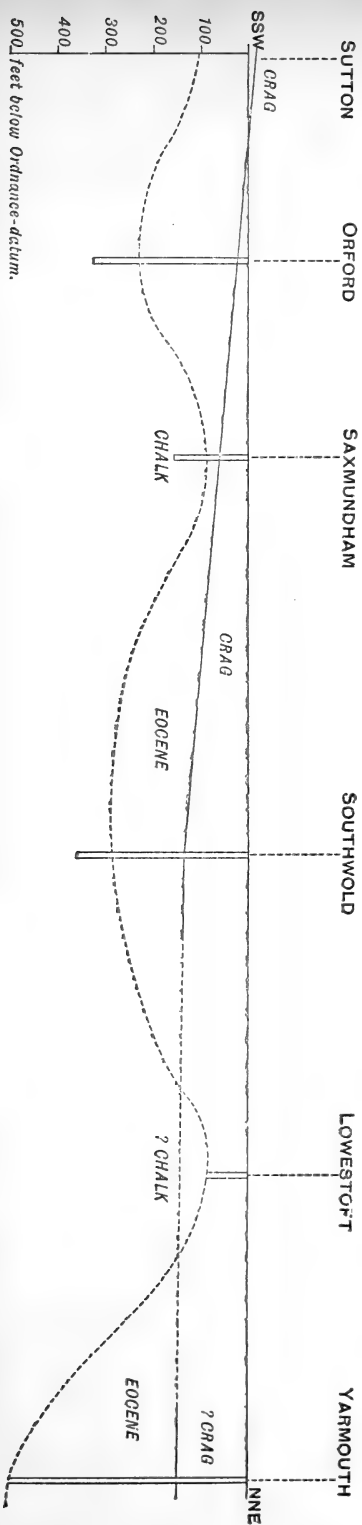
<sup>6</sup> Whitaker, *Mem. Geol. Surv. Southwold*, 1887, p. 78.

<sup>7</sup> *Mem. Geol. Surv. Southwold*, 1887, p. 4. The Lowestoft boring is cited by Mr. Whitaker on the authority of Mr. A. A. Langley. The presence of the Chalk so near the surface at that place appears improbable. May it not have been the Chalky Boulder Clay that was met with? It is known that this deposit occurs in the Waveney Valley at a considerable depth below the alluvium. In the section (fig. 1) I have shown the Chalk at Lowestoft with a query.

<sup>8</sup> *Quart. Journ. Geol. Soc. vol. xvi.* (1860) p. 450.



Fig. 1.—Section from Sutton to Yarmouth.



and the Crag from Norwich to Bramerton, produced eastward in the direction of Yarmouth, very nearly intersects the base-line of the Pliocene beds under that town.

When we pass to the other side of the North Sea and of the English Channel, we find evidence of similar earth-movements, but on a larger scale. While an elevation of the southern portion of the Pliocene area, corresponding to that at Lenham, has taken place in Belgium and in the North-east of France, the northerly depression has in Holland reached a total depth, possibly, of more than 1500 feet. (See section, fig. 3, p. 753.)

In a map published in 1887,<sup>1</sup> from which the distribution of the Pliocene beds of Belgium in the accompanying sketch-map (Pl. XXXIV.) has been taken, the eminent Belgian geologist M. E. Van den Broeck has shown a chain of outliers of Diestien deposits, generally capping isolated hills, extending from Cape Blanc Nez, near Calais, where they attain an elevation of about 500 feet, through Cassel, Tournai, Grammont, and Brussels to Louvain, at which place, however, they are not more than 195 feet above the sea. From Louvain, Diestien strata extend in a continuous sheet, covering a considerable extent of country to the N.E. Mr. Clement Reid connects these Belgian and French beds with those at Lenham, by a belt of outliers of similar ferruginous sandstone, occurring on the English side of the Channel near the Chalk escarpment between Folkestone and the river Stour.<sup>2</sup> It is considered by M. Van den Broeck that these deposits indicate generally the southern boundary of the Diestien sea. In passing I may say that M. G. F. Dollfus, the President of the Geological Society of France, insists that this sea was closed to the south,<sup>3</sup> but the marked resemblance between the molluscan fauna of the Coralline Crag (the English equivalent of the upper part of the Diestien formation)<sup>4</sup> and that of the Lusitanian and Mediterranean areas at the present day makes me tenacious of the hypothesis that there was at the period in question direct communication between the Anglo-Dutch basin and the Atlantic.<sup>5</sup> If the line from Louvain to Lenham, indicated by this chain of deposits, formed the continuous margin of the Diestien sea, it may still have been connected with the south-west by means of a strait over some part of the southern counties of England.<sup>6</sup> Whether or not the sea of the Coralline Crag

<sup>1</sup> Bull. Soc. Belge Géol. vol. i. pl. ii.

<sup>2</sup> 'The Pliocene Deposits of Britain,' Mem. Geol. Surv. 1890, p. 49.

<sup>3</sup> Rep. Brit. Assoc. Ipswich (1895) p. 691.

<sup>4</sup> While agreeing with Mr. Reid that the Lenham Beds are equivalent to the ferruginous Diestien Sands of Belgium, the study of the fauna of Lenham leads me to think that the deposit may be slightly older than the Coralline Crag. The latter is evidently of similar age to the Belgian 'zone à *Isocardia Cor.*' which M. Van den Broeck considers to be the upper part, while the sands of Cassel, etc., are, in his opinion, the lower part of the Diestien formation. Of the species of mollusca known from the *Isocardia*-beds 87 per cent. occur in the Coralline Crag.

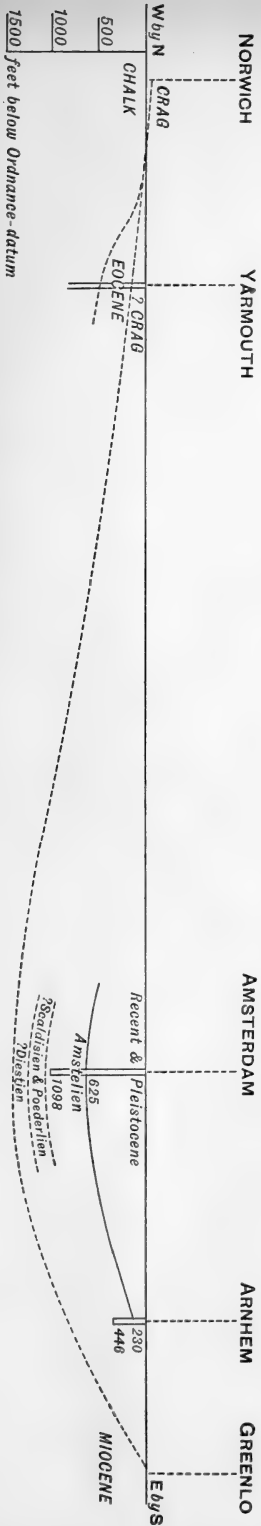
<sup>5</sup> See Geol. Mag. 1896, p. 27.

<sup>6</sup> It may be accidental, but perhaps it is worthy of notice, that the triangular shape of the Red Crag area between Saxmundham and Sudbury, with its apex pointing to the S.W. (see map, Pl. XXXIV.), seems almost to suggest that a depression, from which the sea was gradually retreating as the southerly elevation went on, may have formerly existed in that direction.

Fig. 2.—Section from Norwich to Yarmouth.



Fig. 3.—Section from Norwich to Greenlo.



was closed to the north may be regarded as an open question, but the almost total absence of boreal shells from that formation seems in favour of the latter view. If this was so, the combined movement of elevation and depression which followed the deposition of the Older Pliocene probably created a land-barrier which prevented the further access of warm currents from the south, while communication with northern seas was opened up, and this was probably one of the causes of the gradual change in the facies of the molluscan fauna which is characteristic of the Upper Crag.

In Belgium this elevation caused the sea to retreat in a northerly direction. Diestien strata occur in that country about 25 miles farther south than do the shallow-water Scaldisien deposits which rest on them,<sup>1</sup> implying in M. Van den Broeck's opinion a northward shifting of the shore-line previously to the deposition of the latter, while before the upper beds of the English Crag came into existence the sea had altogether retired from Belgium. A similar change in the southern margin of the Newer Pliocene basin, due to the same cause, may be traced in East Anglia. The oldest deposits of the Upper Crag, namely, those at Walton, are found only at or near that place,<sup>2</sup> that is at the southern extremity of the Crag area, the succeeding horizons of Sutton, Butley, Norwich, and Weybourn, as pointed out by Mr. Wood and myself many years ago, being represented by beds occurring successively in positions farther north.

At Antwerp, the Newer Pliocene strata (Scaldisien and Poederlien) are thinly represented, attaining a maximum thickness of about 12 or 15 feet, and are exposed only below the water-level. They increase in thickness to the north, and in Holland are covered by a great mass of still more recent Pliocene and Pleistocene beds, which rapidly thicken in a northerly direction, and reach at Amsterdam, if my classification of these deposits be correct, the extraordinary thickness of more than 1000 feet. Dr. Lorie has given, in the works before alluded to, descriptions of the strata met with in borings at Goes, Gorkum, Utrecht, Arnhem, and Amsterdam, as well as careful lists of the fossils discovered at different depths. He recognizes at these places, in addition to the recent alluvium on the one hand, and the Rupelien which was reached at Goes, on the other, the presence of three formations, namely, 'Quaternaire,' Scaldisien, and Diestien. Mr. Clement Reid expressed the opinion in 1889 that the Scaldisien deposits of Belgium represent, not the whole of the Red Crag, but its lowest or Walton stage only, and

<sup>1</sup> M. Van den Broeck says, 'Le Scaldisien tout entier est lui-même un dépôt essentiellement côtier et littoral.'

<sup>2</sup> I cannot agree with Mr. Reid ('Pliocene Deposits,' etc. p. 85) that the bed at Beaumont, 5 miles from Walton, described by Mr. J. Brown, of Stanway, 50 years ago, should be referred to the Upper Red Crag. With very few exceptions the shells recorded from that locality occur at Walton or in the Coralline Crag, and most of them abundantly. Two northern species are mentioned, however, *Astarte borealis* and *Scalaria similis* (*grœnlandica*), which have not been found at Walton; but the former is not a Red Crag shell at all, having made its first appearance in the Norwich beds. Mr. Wood had great doubt whether these specimens had been correctly identified. The sinistral variety of *Trophon antiquus*, the characteristic shell of the Walton horizon, occurs at Beaumont, but not the dextral form.

that no beds equivalent to its upper horizons were known either in Belgium or Holland.<sup>1</sup> A careful analysis of the different faunas induces me to agree with him as to the two first propositions, but not as to the third. It seems to me that the upper and by far the larger of the Dutch beds regarded by Dr. Loricé as Scaldisien are considerably more recent than that formation.<sup>2</sup>

The resemblance between the Walton Crag and the Scaldisien (including the Poederlien) of Belgium is very close. Among the mollusca found at Walton there are 120 which occur abundantly, and which may be taken as representative species,<sup>3</sup> and of these 91 are found in the latter deposits. Both are characterized by the first appearance and the great abundance of the sinistral form of *Trophon* (*Chrysodomus*) *antiquus*.<sup>3</sup> The dextral variety has not been met with in the Scaldisien, and a single specimen of it only in an upper bed at Walton, but it appears in increasing abundance in the later beds of the Crag, where the left-handed form becomes correspondingly scarce.

Among the rarer mollusca of these deposits there are a number of extinct and southern species,<sup>4</sup> which were apparently dying out at that period, as many of them are abundant in the Coralline, but are not found in the upper beds of the Red Crag. The latter moreover contain northern shells, including the Arctic forms *Buccinum grænlandicum*, *Scalaria grænlandica*, *Amaura candida*, *Natica grænlandica*, *N. helicoides*, *Leda lanceolata*, *L. minuta*, and *Cardium grænlandicum*, which are not known either in the Scaldisien or from Walton or any older horizon.

In the Poederlien, a slightly newer zone, which has recently been separated from the Scaldisien by M. Vincent, the dextral form of *Trophon* occurs, though not abundantly, associated with a few specimens of the northern but not exclusively Arctic shell *Chrysodomus despecta*, but these are not characteristic of the fauna, the general facies of which is southern rather than northern. There is very little difference between the Scaldisien and the Poederlien. With few exceptions, the species of mollusca found in them are common to both, and they are not more unlike than the lower is to the upper bed at Walton. From the latter, as from the Poederlien, a fauna slightly more boreal than that of the bed underlying it has been obtained.<sup>5</sup>

The following lists show—A, the species abundant at Walton which are found also in the Scaldisien and Poederlien; B, the extinct and southern forms occurring in them, but not in the upper Red Crag; and C, the northern and recent shells characteristic of the latter, which are not present in the older beds.

<sup>1</sup> 'Pliocene Deposits,' etc. p. 211.

<sup>2</sup> I am indebted for this information to Mr. P. F. Kendall, F.G.S.

<sup>3</sup> The Scaldisien was originally called the 'Zone à *Trophon antiquum*.'

<sup>4</sup> 44 extinct and 17 southern in the Scaldisien (including the Poederlien), and 40 extinct and 11 southern at Walton.

<sup>5</sup> The distinction between the upper and lower beds at Walton was first pointed out by Mr. Kendall.

TABLE A.

List of Mollusca occurring abundantly at Walton, which are also found in the Scaldisien and Poederlien of Belgium.<sup>1</sup>

	Scaldisien.	Poederlien.	Not known living.	Southern.		Scaldisien.	Poederlien.	Not known living.	Southern.
GASTEROPODA.					PELECYPODA.				
<i>Cypræa avellana</i> , Sow. ....	+	+	+		<i>Anomia ephippium</i> , Linn. ....	+	+		
„ <i>europæa</i> , Mont. ....	+	+	+		„ <i>striata</i> , Broc. ....	+	+		
<i>Voluta Lamberti</i> , Sow. ....	+	+	+		<i>Ostrea edulis</i> , Linn. ....	+	+		
<i>Columbella sulcata</i> , Sow. ....	+	+	+		<i>Pecten pusio</i> , Linn. ....	+	+		
<i>Nassa elegans</i> , Leathes ....	+	+	+		„ <i>opercularis</i> , Linn. ....	+	+		
„ <i>labiosa</i> , Sow. ....	+	+	+		„ <i>maximus</i> , Linn. ....	+	+		
„ <i>prismatica</i> , Broc. ....	+	+	...	+	„ <i>tigrinus</i> , Müll. ....	+	+		
„ <i>granulata</i> , Sow. ....	+	+	?	+	<i>Mytilus edulis</i> , Linn. ....	+	+		
„ <i>propinqua</i> , Sow. ....	+	+	+		<i>Pectunculus glycimeris</i> , Linn. ...	+	+		
„ <i>reticosa</i> , Sow. ....	+	+	+		„ var. <i>subobliquus</i> , Wood	+	+		
<i>Buccinopsis Dalei</i> , Sow. ....	+	+	+		<i>Nucula lævigata</i> , Sow. ....	+	+	+	
<i>Buccinum undatum</i> , Linn. ....	+	+	+		„ <i>nuculus</i> , Linn. ....	+	+		
<i>Purpura lapillus</i> , Linn. ....	+	+	+		<i>Montacuta bidentata</i> , Mont. ...	+	+		
„ <i>incrassata</i> , Sow. ....	+	+	+		<i>Scintilla ambigua</i> , Nyst ....	+	+	+	
„ <i>tetragona</i> , Sow. ....	+	+	+		<i>Lucina borealis</i> , Linn. ....	+	+		
<i>Trophon contrarius</i> , Linn. ....	+	+	...	+	<i>Cardita corbis</i> , Phil. ....	+	+	...	+
„ <i>gracilis</i> , Da Costa ....	+	+	...	+	„ <i>scalaris</i> , Leathes ....	+	+	...	+
„ <i>muricatus</i> , Mont. ....	+	+	...	+	<i>Cardium edule</i> , Linn. ....	+	+		
<i>Pleurotoma lævigata</i> , <sup>2</sup> Phil. ....	+	+	...	+	„ <i>nodosum</i> , Turt. ....	+	+		
„ <i>brachystoma</i> , Phil. ....	+	+	...	+	„ <i>Parkinsoni</i> , Sow. ....	+	+	+	
<i>Cerithium tricinatum</i> , Broc. ....	+	+	+		„ <i>decorticatum</i> , Wood ...	+	+	+	
„ <i>varicosum</i> , Nyst ....	+	+	+		<i>Cyprina islandica</i> , Linn. ....	+	+		
<i>Aporrhais pes-pelecani</i> , Linn. ...	+	+	+		<i>Astarte obliquata</i> , Sow. ....	+	+	+	
<i>Turritella incrassata</i> , Sow. ....	+	+	...	+	„ <i>Burtinii</i> , de Laj. ....	+	+	+	
<i>Chemnitzia elegantior</i> , Wood ...	+	+	+		„ <i>Omalii</i> , de Laj. ....	+	+	+	
„ <i>internodula</i> , Wood ...	+	+	+	+	„ <i>Basterotii</i> , de Laj. ....	+	+	+	
<i>Lacuna suboperta</i> , Sow. ...	+	+	+		<i>Woodia digitaria</i> , Linn. ....	+	+	...	+
<i>Natica catenoides</i> , Wood ...	+	+	+		<i>Venus casina</i> , Linn. ....	+	+		
„ <i>hemiclausula</i> , Sow. ....	+	+	+		<i>Cytherea rudis</i> , Poli. ....	+	+	...	+
„ <i>multipunctata</i> , Lam. ....	+	+	+		<i>Artemis lentiformis</i> , Sow. ....	+	+	+	
<i>Trochus noduliferens</i> , Wood ...	+	+	+		„ <i>lincta</i> , Pult. ....	+	+		
„ <i>Adansoni</i> , Payr. ....	+	+	...	+	<i>Gastrana laminosa</i> , Sow. ....	+	+	...	+
„ <i>Montacuti</i> , W. Wood. ....	+	+	...	+	<i>Tapes virgineus</i> , Linn. ....	+	+		
„ <i>zizyphinus</i> , Linn. ....	+	+	+		<i>Tellina crassa</i> , Penn. ....	+	+		
<i>Fissurella græca</i> , Phil. ....	+	+	...	+	„ <i>donacina</i> , Linn. ....	+	+	...	+
<i>Emarginula fissura</i> , Linn. ....	+	+	...	+	<i>Abra alba</i> , Wood ...	+	+		
<i>Calyptræa chinensis</i> , Linn. ....	+	+	...	+	<i>Maetra arcuata</i> , Sow. ....	+	+	+	
<i>Capulus ungaricus</i> , Linn. ....	+	+	...	+	„ <i>subtruncata</i> , Da Costa ...	+	+		
<i>Tectura virginea</i> , Müll. ....	+	+	...	Nth <sup>a</sup>	<i>Pandora inæqualis</i> , Linn. ...	+	+		
<i>Actæon Noë</i> , Sow. ....	+	+	...	+	<i>Solen ensis</i> , Linn. ....	+	+		
<i>Bulla cylindracea</i> , Penn. ....	+	+	...	+	„ <i>gladiolus</i> , Gray ....	+	+	...	Nth <sup>a</sup>
<i>Conovulus pyramidalis</i> , Sow. ....	+	+	+		<i>Corbula gibba</i> , Nyst ....	+	+	+	
<i>Dentalium dentalis</i> , Linn. ....	+	+	...	+	<i>Corbulomya complanata</i> , Sow. ...	+	+	+	
					<i>Saxicava rugosa</i> , Linn. ....	+	+		
					<i>Panopea Faujasii</i> , de la G. ...	+	+	...	+
					<i>Mya arenaria</i> , Linn. ....	+	+		
					„ <i>truncata</i> , Linn. ....	+	+		
					<i>Cochlodesma complanata</i> , Wood. ...	+	...	+	

<sup>1</sup> In this and the following lists the more abundant species are indicated by thicker crosses.

<sup>2</sup> [The genders originally adopted in the nomenclature have been retained throughout these lists of fossils at the author's request.—Ed.]

Of the 90 species just named 28 are extinct, 19 are southern, and 2 northern. Most of them, it will be observed, are abundant in the Belgian beds.

This list shows the close resemblance between the Scaldisien and Poederlien. The principal difference between them is that in the latter occur, though not abundantly, the dextral form of *Trophon* (*Chrysodomus*) *antiquus*, and the northern species *Tr. gracilis* and *Tr. despectus*.

TABLE B.

*Extinct or Southern Species found in the Scaldisien or Poederlien of Belgium, but not in the Amstelien or at the Butley horizon of the Red Crag. (Atl.=Atlantic.)*

	Scaldisien.	Poederlien.	Coralline Crag.	Diestien.	Walton Crag.	Not known living.	Southern.
GASTEROPODA.							
<i>Trophon alveolatus</i> , Sow. ....	+	+	+	+	+	+	
<i>Cancellaria mitriformis</i> , Broc. ....	+	+	+	...	...	...	+
<i>Nassa prismatica</i> , Broc. ....	+	+	+	...	...	+	+
" <i>lamellilabra</i> , Nyst ....	+	+	...	...	...	+	
<i>Murex Duponti</i> , Nyst ....	...	+	...	...	...	+	
" <i>vicinus</i> , Nyst ....	...	+	...	...	...	+	
<i>Cancellaria Lajonkairi</i> , Nyst ....	+	+	...	+	...	+	
" <i>umbilicaris</i> , Broc. ....	+	+	...	...	...	+	
<i>Columbella subulata</i> , Broc. ....	+	+	...	...	...	...	+
† " <i>sulcata</i> , Sow. ....	+	...	+	...	+	+	
<i>Pleurotoma festiva</i> , Hornes ....	+	+	...	...	...	+	
" <i>gracilis</i> , Mont. ....	+	+	...	...	...	+	
" <i>hystrix</i> , Jan ....	...	+	...	...	+	...	+
" <i>incrassata</i> , Duj. ....	...	+	...	...	...	...	+
" <i>perpulchra</i> , Wood ....	+	+	+	...	+	+	
" <i>similis</i> , Nyst ....	+	+	...	...	...	+	
" <i>subulata</i> , Nyst ....	...	+	...	...	...	+	
† <i>Drillia crassa</i> , A. Bell ....	+	+	+	+	+	+	
" <i>crispata</i> , Jan ....	+	...	+	...	...	...	+
<i>Hædropleura Delheidi</i> , Vin. ....	...	+	...	...	...	+	
<i>Natica cirriformis</i> , Sow. ....	+	...	+	+	...	...	+
" <i>intermedia</i> , Phil. ....	+	+	...	...	...	+	
<i>Turbonilla similis</i> , Wood ....	...	+	+	+	...	+	
" <i>semistriata</i> , Wood ....	+	...	...	...	...	+	
<i>Eulima subulata</i> , Don. ....	+	+	+	+	+	...	+
<i>Pyramidella plicosa</i> , Brown ....	+	+	+	+	+	+	
<i>Cæcum trachea</i> , Mont. ....	+	...	+	...	...	...	+

† These are reported from Butley by Mr. A. Bell, but are not recognized as Butley fossils by Mr. Wood or Sir J. Prestwich.

TABLE B (continued).

	Scaldisien.	Poederlien.	Coralline Crag.	Diestien.	Walton Crag.	Not known living.	Southern.
<b>GASTEROPODA (continued).</b>							
<i>Scalaria fimbriosa</i> , Wood .....	...	+	+	..	+	+	
„ <i>frondicula</i> , Wood .....	+	+	+	+	..	..	+
+ „ <i>subulata</i> , Sow. ....	+	+	+	+	+	+	
<i>Fossarus lineolatus</i> , Wood .....	+	..	+	+	..	..	+
<i>Rissoa obsoleta</i> , Wood .....	+	+	+	..	..	+	
„ <i>proxima</i> , Alder .....	+	+	+	+	..	..	+
<i>Xenophorus Deshayesi</i> , Mich. ....	+	..	..	..	..	+	
<i>Trochus obconicus</i> , Wood .....	+	+	+	?	..	+	
„ <i>turbinoides</i> , Nyst .....	..	+	+	+	+	+	
<i>Capulus obliquus</i> , Wood .....	..	+	+	..	+	+	
<b>PELECYPODA.</b>							
<i>Pecten lineatus</i> , Da Costa .....	+	+	..	+	..	+	
<i>Limopsis pygmaea</i> , Phil. ....	+	..	+	+	+	..	+
<i>Nucinella ovalis</i> , Wood .....	+	..	+	+	..	+	
<i>Leda semistriata</i> , Wood .....	+	+	+	+	..	+	
<i>Lucina crenulata</i> , Ald. ....	..	+	+	..	..	+	
„ <i>decorata</i> , Wood .....	..	+	+	..	+	+	
<i>Kellia coarctata</i> , Wood .....	+	+	+	+	..	+	
„ <i>pumila</i> , Wood .....	..	+	+	..	..	Atl.	
<i>Montacuta truncata</i> , Wood .....	+	..	+	..	..	+	
<i>Lepton depressum</i> , Nyst .....	+	+	+	+	..	+	
<i>Astarte incerta</i> , Wood .....	+	+	..	+	..	+	
„ <i>corbuloides</i> , de Laj. ....	+	+	..	+	..	+	
„ <i>parvula</i> , Wood .....	+	..	+	..	..	+	
„ <i>triangularis</i> , Mont. ....	+	+	+	..	..	..	+
<i>Tapes striatella</i> , Nyst .....	+	+	..	..	..	+	
<i>Coralliophaga cyprinoides</i> , Wood .....	+	+	+	..	..	+	
<i>Tellina compressa</i> , Broc. ....	..	+	+	+	..	..	+
„ <i>donacina</i> , Linn. ....	+	+	+	..	+	..	+
<i>Donax subfragilis</i> , d'Orb. ....	..	+	..	..	..	+	
<i>Cultellus tenuis</i> , Phil. ....	+	+	..	+	..	+	
<i>Solenocurtus strigillatus</i> , Linn. ....	+	+	+	..	..	..	+
<i>Thracia ventricosa</i> , Phil. ....	..	+	..	?	..	+	
<i>Cochlodesma complanatum</i> , Wood .....	+	..	..	..	+	+	
<i>Pandora pinna</i> , Mont. ....	+	..	..	..	..	+	

A large proportion of these are rare in the Scaldisien  
and Poederlien.



TABLE C.

*Species of Mollusca, principally Northern or Recent, found in the Amstelian or the Upper Red Crag, but not at Walton or in the Scaldisien of Belgium. (N.A.=North American.)*

	Amstelian.	Upper Red Crag.	Arctic.	Scandinavian.		Amstelian.	Upper Red Crag.	Arctic.	Scandinavian.
GASTEROPODA.					PELECYPODA.				
<i>Buccinum grælandicum</i> , Chem. ....	+	+	+		<i>Modiola modiolus</i> , Linn. ....	+			
<sup>1 2</sup> <i>Trophon antiquus</i> , Linn. ....	+	+	+		<i>Leda lanceolata</i> , Sow. ....	+	+	+	
1 " <i>despectus</i> Linn. ....	+	+	+		" <i>myalis</i> , Couth. ....	+	+	+	N.A.
" <i>Sarsii</i> , Jeffr. ....	+	+	+		" <i>minuta</i> , Mont. ....	+	+	+	+
" <i>Turtoni</i> , Bean ....	+	+	+		" <i>hyperborea</i> , Lovén ....	+	+	+	+
2 " <i>scalariformis</i> , Gould ....	+	+	+	+	<i>Loripes divaricatus</i> , Linn. ....	+	+	+	
<i>Pleurotoma pyramidalis</i> , Strom. ....	+	+	+	+	<i>Cardium grælandicum</i> , Chem. ....	+	+	+	
" <i>violacea</i> , M. & A. ....	+	+	+	+	<sup>2</sup> <i>Astarte compressa</i> , Mont. ....	+	+	+	+
<i>Cancellaria viridula</i> , Fabr. ....	+	+	+	+	<i>Tellina lata</i> , Gmel. ....	+	+	+	
<i>Scalaria grælandica</i> , Chem. ....	+	+	+	+	1 " <i>obliqua</i> , Sow. ....	+	+	+	
<i>Littorina littorea</i> , Linn. ....	+	+	+		1 " <i>pratensis</i> , Leathes ....	+	+	+	
<i>Amaura candida</i> , Möll. ....	+	+	+		<i>Macra ovalis</i> , Sow. ....	+	+	+	
2 <i>Natica clausa</i> , B. & S. ....	+	+	+	+	1 <i>Solen siliqua</i> , Linn. ....	+	+	+	
" <i>grælandica</i> , Beck ....	+	+	+	+					
" <i>helicoides</i> , Johns. ....	+	+	+	+	BRACHIOPODA.				
" <i>occlusa</i> , Wood ....	+	+	+	+	<i>Rhynchonella psittacea</i> , Chem. ....	+	+	+	+
<i>Melampus fusiformis</i> , Wood ....	+	+	+	+					

I do not think that the facts which I have stated leave any room for doubt that the Scaldisien and Poederlien of Belgium are equivalent to the Walton stage of the Red Crag, and not to the whole of that formation, and that the Butley horizon of the Red Crag is not represented in Belgium at all. I hope to show, however, that its equivalent exists in Holland.<sup>3</sup>

While the Belgian area had thus been converted into land, and in England the sea had retreated northward from Walton before the deposition of the later beds of the Crag, an entirely different state of things obtained in Holland. There the sea-bottom was subsiding, and we must have in the subsoil of that country a continuous series of the beds deposited during the progress of the subsidence, equivalent to different stages of the English Crag.<sup>4</sup> We do find the same

<sup>1</sup> These have been found in the Poederlien, but not in the Scaldisien.

<sup>2</sup> Mr. Kendall has obtained one or two specimens of each of these at Walton, as the result of many weeks' work. On the other hand, a number of the species in this list are among the more abundant forms of the Upper Red Crag and of the Amstelian.

<sup>3</sup> Since the above was written, I have noticed that a similar opinion was expressed in 1872 by Mr. A. Bell, Geol. Mag. p. 211.

<sup>4</sup> In Belgium a break undoubtedly exists between the Diestien and the Scaldisien; but, for the reasons stated, it may have been otherwise in Holland.

change in the mollusca of both deposits, namely, the gradual dying-out of older and southern forms and the gradual appearance of northern and more recent species. The evidence which we possess from the Dutch beds is, it is true, at present but small, and, so far as it is negative, it cannot be regarded as of great value. As to the positive evidence, the occurrence of certain species at certain depths, the case is different, and we may draw our conclusions from it with more confidence. It may perhaps be urged that the total number of species (about 150) is insufficient to form a representative collection of the mollusca living in these seas during the Pliocene epoch, but if the view I have elsewhere taken, that the general facies of the fauna of any bed must be gained from the species which occur abundantly in it, rather than from all which can be discovered,<sup>1</sup> these shells may have more value than at first appears. The chances are that it is the characteristic forms which have been met with, and it is worthy of notice that the fauna of each horizon has a distinctive and probably a representative character.

The section (fig. 4) illustrating the views now held is drawn to scale from Cassel, a small town in French Flanders, 27 miles N.W. of Lille, to Amsterdam, a distance of about 150 miles. At Cassel, Diestien beds are found, resting on Eocene strata (Asschien), capping the summit of a hill 515 feet above the sea-level. Passing thence to the N.E., we find, at Ostend, Eocene beds covered by 120 feet of recent and Pleistocene deposits, the latter containing *Cyrena fluminalis*,<sup>2</sup> a freshwater and southern shell which occurs occasionally in the Upper Crag, but which is very characteristic of one of the English post-Glacial horizons. No Diestien beds are present at Ostend, nor was *Cyrena fluminalis* detected in any of the Dutch borings.<sup>3</sup>

Still farther to the N.E., at Goes, in South Beveland, Scaldisien strata were reached at 114 feet, and Diestien at 183 feet below Ordnance datum, at about which depth 20 species of echinodermata and polyzoa, and 35 species of mollusca, all characteristic forms of the Coralline Crag, were obtained. Oligocene deposits (Rupelien) were found at 304 feet, showing the Diestien to be 121 feet in thickness. Between 94 and 114 feet, a bed was observed containing *Cardium groenlandicum*, which Dr. Lorié regards as Pleistocene, but I suggest that it may be the equivalent of those which attain so great a thickness in the other borings, and, I believe, represent an upper division of the English Crag. Dr. Lorié states that at Goes no satisfactory division can be made on lithological grounds between the Pliocene and what he regards as Pleistocene deposits.

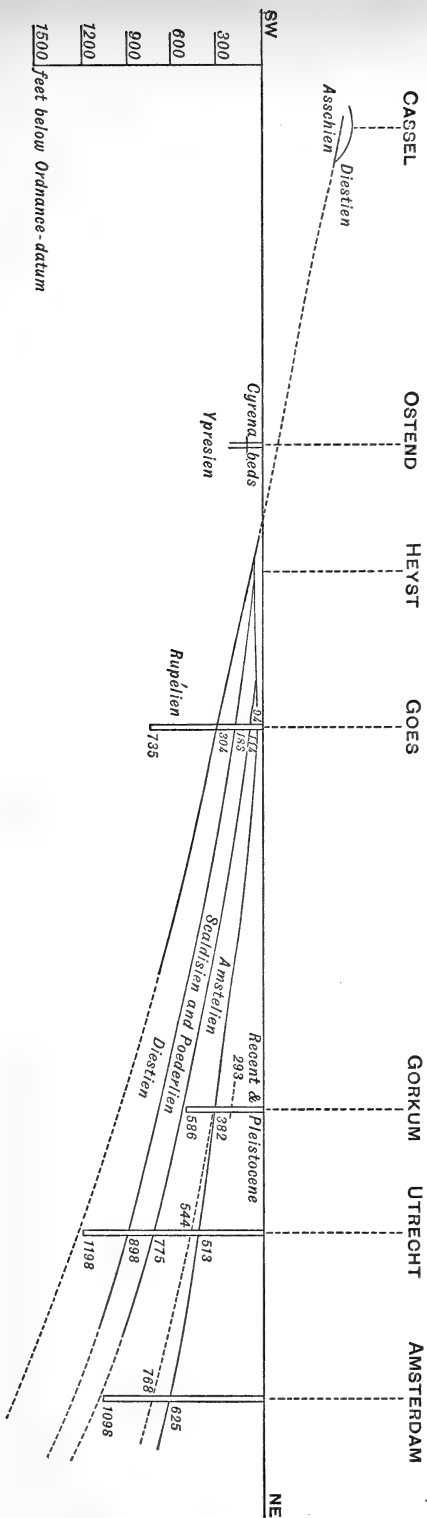
In the boring at Gorkum, or Goringhem, about 50 miles E.N.E. of Goes, the Diestien was not reached, even at a depth of 586 feet. Between 293 and 382 feet a bed was met with containing land and

<sup>1</sup> Geol. Mag. 1896, p. 27.

<sup>2</sup> Dollfus, Mém. Soc. Roy. Malacolog. Belg. vol. xix. (1884).

<sup>3</sup> I am informed by M. Moulon that *Cyrena fluminalis* is found at all levels in the Flandrien (Upper Pleistocene) of Belgium, deposits which have been proved by boring to be in places 150 feet thick.

Fig. 4.—Section from Cassel to Amsterdam.



freshwater shells, which Dr. Lorié considers to be 'Quaternaire.' Similar species occur at Utrecht and Amsterdam, associated with marine mollusca of Pliocene age, such as *Nucula Cobboldiae* and *Tellina prætenuis*. In the section (fig. 4) I have drawn the base of the Pleistocene where Dr. Lorié puts it, but I have also indicated by dotted lines the limits within which land and freshwater species have been found. Dr. Lorié classes the strata found at Gorkum below 382 feet as Scaldisien. They contain, however, *Leda lanceolata*, and other shells, not known either from Walton or the Scaldisien of Belgium, and which have not been found in the Dutch borings in what I consider to be undoubtedly Scaldisien strata. It seems to me that all the Gorkum beds are newer than the Scaldisien.

The Utrecht boring was carried down to the great depth of 1198 feet. At this place Dr. Lorié concludes, chiefly on lithological grounds, that Diestien strata were reached at 775 feet. He points out that at that depth an abrupt change takes place in the appearance and character of the sediment, yellow sands, without glauconite, being replaced by grey sands containing that mineral.<sup>1</sup> As, however, the Scaldisien beds of Antwerp and Goes contain glauconite,<sup>2</sup> this fact does not seem of sufficient importance to outweigh the palæontological evidence, which induces me to think that the division between the Scaldisien and the Diestien should be placed somewhat lower, namely, at 898 feet, and that the line of 775 feet should be regarded as the division between the Scaldisien and the more recent beds. Similarity of composition is not always a conclusive test of age. The material now covering the bottom of the British seas is not by any means uniform over considerable areas, while beds which closely resemble each other may be of different age. The principal part of the material of which the Dutch beds are composed was, no doubt, brought down by the Rhine and the rivers associated with it. The nature of these different sediments would remain more or less the same during long periods of time, but they might be deposited now in one place, and now in another.<sup>3</sup>

At Utrecht the freshwater species, *Succinea elegans*, was met with between 521 and 542 feet,<sup>4</sup> at a level (though somewhat higher) corresponding to that of the bed containing land and freshwater shells at Amsterdam, to be alluded to hereafter. Between 513 and 775 feet at Utrecht strata were passed through containing *Nucula Cobboldiae*, *Tellina prætenuis*, and the Arctic forms, *Leda lanceolata*, *Cardium grœnlandicum*, and *Natica clausa*, with other shells representative of our Upper Crag: these deposits seem to me as recent as the Red Crag horizons of Sutton or Butley. Below this depth, from 775 to 898 feet, were found what I consider to be

<sup>1</sup> The yellow colour of the former may possibly be due to the decomposition of the glauconite.

<sup>2</sup> Lithologically the Diestien and Scaldisien sands are almost identical.

<sup>3</sup> Some of the beds described by Dr. Lorié seem to be similar in character to the Chillesford Clay of East Anglia, though they are of different age.

<sup>4</sup> One specimen only was found at 644 feet.

true Scaldisien strata, containing species characteristic of those deposits and of the Walton Crag, and especially the representative form *Trophon* (*Chrysodomus*) *contrarius*, unknown from the Diestien or the Coralline Crag. Below 898 feet the boring passed through beds containing the usual Diestien fossils for 300 feet farther, reaching a total depth of 1198 feet, but not the base of the Diestien formation.

The borings at Amsterdam, which were carried to a depth of 1098 feet below Ordnance-datum, show that the dip of the Pliocene and Pleistocene strata continues as far north as that city. The bed containing land and freshwater shells consequently occurs at a lower level than that at Utrecht, namely, at about 768 feet.

I suggest that all the strata below the Pleistocene met with here (except perhaps the last 48 feet, which do not contain fossils) represent an upper zone of the English Crag, and that the Scaldisien was not reached. In addition to most of the boreal species recorded from this horizon at the other localities, there were found in this boring *Leda myalis*, a characteristic shell of the latest Pliocene beds, *Leda minuta* and *Fusus scalariformis*.<sup>1</sup> Northern shells occur at all depths, though they become less abundant in the lower beds, and there is a marked absence of the Coralline and Walton Crag forms which are present in the Scaldisien.

The greater-part of the Newer Pliocene deposits of Holland are thus, I consider, decidedly more recent than the Scaldisien of Belgium. They cannot be included in that formation because they are separated from it by the Poederlien, a zone which closely resembles the Scaldisien, but differs widely from these deposits. I know of no horizon to which this grand series of strata, more than 400 feet in thickness, can be conveniently referred, and therefore propose for it the name of 'Amstelien.'<sup>2</sup>

It does not seem probable that these Amstelien beds contain any which are equivalent to the Norwich Crag. Some of the common shells of that horizon occur in them, but the most representative, as for example, *Astarte borealis*, *A. compressa*, *A. sulcata*, *Tellina lata*, *Natica catena*, and *N. helicoides*, are conspicuous by their absence. The list of shells from the Amstelien is, however, evidently incomplete, and these species may possibly be discovered in a future boring. But there is not at present any palæontological evidence by which this formation can be divided into zones, except that land and freshwater shells occur only in the upper part.

If the new zone, Amstelien, which I now propose, is generally accepted, it will, I think, involve the separation of the Walton bed from the Red Crag, but I have for some time thought that separation desirable. The difference between the faunas of these two deposits

<sup>1</sup> The shells from the boring at Arnhem were not preserved, with the exception of a few specimens of recent species, which were found at a depth of 429 feet.

<sup>2</sup> The name 'Amstelien,' suggested to me as an appropriate one by Dr. Loricé, is taken from that of the river Amstel, upon which stands the city of Amsterdam, where these beds have their greatest known development.

is considerably greater than that between the upper portion of the Red and the Norwich Crags.

I have been guided entirely by palæontological considerations in attempting to separate, in these borings, the different horizons of the Dutch Crag. The lines that I have drawn may or may not be correct, and I am quite prepared to adjust them if necessary. But even if they may have to be shifted higher or lower, it will not, I think, affect the general conclusions, that three divisions rather than two may be traced in these strata; that Arctic shells are confined to the highest zone; and that there is an absence from the latter of a number of extinct or southern forms which are found alike in the Scaldisien and Walton deposits, but not in the upper horizons of the English Crag.

The difference between the three divisions of the Dutch Crag comes out more distinctly when we confine our attention to the more abundant or characteristic species. I subjoin lists of these, extracted from the general list given by Dr. Loricé.

LIST of the more abundant species of MOLLUSCA from the  
PLIOCENE BEDS of HOLLAND.

A. From beds regarded by me as Diestien.<sup>1</sup>

<i>Terebratula grandis</i> , Blum.	<i>Astarte Omalii</i> , de Laj.
<i>Anomia ephippium</i> , Linn.	" <i>triangularis</i> , Mont.
<i>Pecten opercularis</i> , Linn.	<i>Woodia digitaria</i> , Linn.
" <i>ventilabrum</i> , Goldf.	<i>Venus ovata</i> , Penn.
<i>Limopsis pygmæa</i> , Wood.	<i>Corbula gibba</i> , Olivi
<i>Cardita orbicularis</i> , Leathes	<i>Dentalium entalis</i> , Linn.
" <i>chamæformis</i> , Leathes	<i>Cyprina islandica</i> , Linn.
" <i>scalaris</i> , Leathes	

These are all Coralline Crag shells and exceedingly abundant in that formation. In addition, there have been found in these beds 35 species of mollusca, 11 of polyzoa, and 3 of echinodermata, characteristic forms of the Coralline Crag.

B. From beds regarded as Scaldisien.

<i>Anomia ephippium</i> , Linn.	<i>Cyprina islandica</i> , Linn.
<i>Pecten opercularis</i> , Linn.	<i>Venus ovata</i> , Penn.
" <i>similis</i> , Laskey	<i>Macra deaurata</i> , Turt.
" <i>ventilabrum</i> , Goldf.	<i>Corbula gibba</i> , Olivi
<i>Mytilus edulis</i> , Linn.	<i>Dentalium entalis</i> , Linn.
<i>Cardita chamæformis</i> , Leathes	<i>Turritella terebra</i> , Linn.
" <i>scalaris</i> , Leathes	" <i>incrassata</i> , Sow.
" <i>orbicularis</i> , Leathes	<i>Fusus gracilis</i> , Da Costa
<i>Astarte Galeottii</i> , Nyst	" <i>contrarius</i> , Linn.
" <i>Omalii</i> , de Laj.	" <i>alveolatus</i> , Sow.
<i>Woodia digitaria</i> , Linn.	<i>Nassa reticosa</i> , Sow.

*Tellina compressa*, *Natica helicina*, *Nassa elegans*, *Fusus antiquus* (dextral), and *Nucula Cobboldiæ*, Red Crag or Scaldisien, but not Coralline Crag forms, are met with at this horizon; with one

<sup>1</sup> For convenience of reference I use the names adopted by Dr. Loricé.

exception the species in this list occur in the Scaldisien or Walton Crag.

### C. From beds regarded as Amstelien.

<i>Anomia ephippium</i> , Linn.	<i>Donax vittatus</i> , Da Costa
<i>Pecten opercularis</i> , Linn.	<i>Tellina obliqua</i> , Sow.
" <i>ventilabrum</i> , Goldf.	" <i>pratensis</i> , Leathes
<i>Mytilus edulis</i> , Linn.	<i>Semele alba</i> , Wood
<i>Nucula Cobboldiæ</i> , Sow.	<i>Mactra solida</i> , Linn.
" <i>lævigata</i> , Sow.	" <i>deaurata</i> , Turt.
<i>Leda lanceolata</i> , Sow.	" <i>subtruncata</i> , Mont.
" <i>myalis</i> , Wood	<i>Mya arenaria</i> , Linn.
<i>Cardium edule</i> , Linn.	" <i>truncata</i> , Linn.
" <i>subturgidum</i> , d'Orb.	" <i>Binghami</i> , Turt.
" <i>grænelandicum</i> , Chem.	<i>Corbula gibba</i> , Olivi
<i>Lucina divaricata</i> , Linn.	<i>Turritella terebra</i> , Linn.
<i>Cyprina islandica</i> , Linn.	<i>Littorina littorea</i> , Linn.
<i>Venus ovata</i> , Penn.	<i>Ringicula ventricosa</i> , Sow.

These are, with one or two exceptions, among the most abundant and characteristic species of the upper horizons of the English Crag. In addition to the above, the following have been found in the Amstelien, though not abundantly:—*Leda minuta*, *Natica clausa*, and *Fusus scalariformis*, Arctic shells, and *Scrobicularia piperata*, an Upper Crag form.

The fossils named in Table A are evidently Diestien, while Table B contains the same kind of admixture of Coralline and Red Crag forms that is characteristic of the Walton bed, which it resembles generally more nearly than any other horizon of the Crag.

The difference between Tables B and C is very marked. The first contains four characteristic southern shells, and one exclusively northern (found also at Walton); the other, one southern (an Upper Crag species), and four northern forms, two of the latter being Arctic. The fauna of Table C presents a more recent facies, resembling that of the Butley Crag, not merely in the presence of boreal shells, but in the absence of many characteristic Walton species. No one familiar with the English Crag would regard this list of mollusca (Table C) as representative of the Walton zone.

The following analysis of all the species of mollusca found at Walton, in the Scaldisien and Poederlien of Belgium, and in the Amstelien of Holland will show, on the one hand, the close resemblance of the three first, and on the other, the great difference between these beds and the latter.

	Not known living.	Cor. Crag or Diestien.	Southern.	Northern.
Walton <sup>1</sup> .....	36 %	71 %	19 %	5.5 %
Scaldisien .....	37 %	75 %	21 %	2.8 %
Poederlien .....	42 %	73 %	17 %	4.6 %
Amstelien .....	30 %	63 %	6.8 %	13.7 %

<sup>1</sup> From information kindly supplied to me by Mr. Kendall. The Walton analysis is taken from the fauna of both the upper and the lower beds.

The difference between the three former and the latter would be much more marked, if we could confine ourselves in each case to the characteristic species.

Among the many exposures of Crag, both in England and on the Continent, we may have deposits representing any part of the Newer Pliocene period, and it is not possible to say that a fossiliferous bed found at any one spot is the exact equivalent of one met with elsewhere, nor to decide in all cases the exact order of superposition of the different deposits; but when we compare, for example, such horizons as the Walton and Butley Crag, the distinction is evident. And there is the same kind of difference between the Scaldisien deposits of Belgium and those for which I propose the name of Amstelian. Looked at broadly, the beds of the Upper Crag of England arrange themselves somewhat in the following order: Walton, Sutton, Butley, Norwich. It cannot be said with certainty that any Belgian or Dutch zone is precisely equivalent to any portion of the English Crag, but the fauna of the Scaldisien and Poederlien resembles most nearly that of the Walton beds, and that of the Amstelian those from Sutton or Butley.

Each division of the Dutch strata increases regularly in thickness in a northerly direction. The Diestien beds, which at Goes are 121 feet, at Utrecht, 65 miles to the N.E., are more than 300 feet thick. The Scaldisien increases in the same distance from 69 to 123 feet, while the Amstelian is 262 feet thick at Utrecht, and more than 450 feet at Amsterdam. At this point, the farthest to the north to which we can carry it, this increment shows no sign of abatement.

The depression in which the Pliocene strata of Holland rest appears to be of the shape of a shallow basin, the sides of which rise to the west, east, and south, towards Norfolk, Germany, and Belgium respectively. Two sections (figs. 3 & 4, pp. 753, 761) illustrating this point are given, namely, from W. to E., and from S.W. to N.E.; but if a third were taken, from S.E. to N.W., that is, from Diest towards Antwerp, it would also show the strata inclining towards the deepest portion of the basin.<sup>1</sup> They are naturally thickest there, but none of them give any indication of having originated in deep water, the presence in the Amstelian of shells such as *Mytilus edulis*, *Cardium edule*, *Donax vittatus*, *Mactra solida*, *Mya arenaria*, *Solen siliqua*, *Scrobicularia piperata*, *Purpura lapillus*, and *Littorina littorea* pointing plainly in an opposite direction.<sup>2</sup> The present case is not one in which sediment has filled up a deep and pre-existing depression, but where the bottom of a shallow sea has continued to subside, *pari passu* with the accumulation of the material brought down into it.<sup>3</sup>

<sup>1</sup> I was equally surprised and interested, when constructing these sections, to find how accurately the details of the different borings fitted in with each other, and with the views expressed in this paper.

<sup>2</sup> The considerable thickness of some of the beds of the Upper Crag in Suffolk, which contain a shallow-water fauna, shows that subsidence was going on there, though not so rapidly as in Holland.

<sup>3</sup> I have no desire to enter here on the discussion of the disputed question whether the accumulation of great masses of sediment in the form of deltas causes the subsidence of the sea-bottom on which they have been deposited.



### III. THE GEOGRAPHICAL CONDITIONS OF THE ANGLO-DUTCH AREA DURING THE VARIOUS STAGES OF THE PLIOCENE EPOCH.

In one of the maps accompanying this paper (Pl. XXXIV.), I have sketched hypothetically, and as far as the evidence will allow, what I consider may have been the distribution of land and sea at the different stages of the Pliocene era. I have taken the lines drawn by M. Van den Broeck as representing approximately the southern limits of the Diestien and Scaldisien basins. I have followed Mr. Clement Reid in connecting the former with Lenham, but I have ventured to bend the line to the S.W. beyond that place, as a suggestion of the manner in which the sea of the Coralline Crag may have communicated with the Atlantic. I have shown the southern limits of the sea of the Walton Crag as occupying a position similar to that of the Scaldisien and Poederlien in Belgium, for it appears probable that the elevatory movement which in that country carried the shore of the Scaldisien sea to the north would in the same manner have affected the English area. The sea of the Walton Crag may possibly have extended over the district now occupied by the Sutton and Butley deposits, traces of its former existence having been removed by denudation, or being concealed below the water-line, but it seems unlikely that it covered those parts of Norfolk in which occur the fluvio-marine strata of the Upper Crag.<sup>1</sup>

The southern boundary of the Amstelien, and of the Upper Red Crag of Suffolk, is drawn to the north of that of the Scaldisien. The Amstelien beds do not extend into Belgium,<sup>2</sup> and in Holland they give indication of thinning out to the south, while in Suffolk the Red Crag of Butley originated, if not as a beach or foreshore-deposit, at any rate at no great distance from the coast.

It appears that after the deposition of the Amstelien beds, that is, at a period not later than that of the Norwich Crag, the subsidence of the Dutch area was arrested, and land conditions were established. It does not seem that any deposits representing the latest horizons of the English Crag were found in these borings, as the eastern margin of the Pliocene sea had been by that time shifted, in consequence of the elevation of the area in question, to the west of the present coast of Holland. Part of the western (the East Anglian) portion of the Pliocene basin was still submerged, and from the strata there deposited some information may be gained as to the geographical conditions of this period.

Mr. Wood and I formerly regarded the Norwich Crag as estuarine, but I now think that it may have originated in a shallow bay, or the embouchure of an estuary,<sup>3</sup> which, however, did not extend so far southward as did the sea of the Butley Crag. The general, though comparatively infrequent, occurrence of land and freshwater

<sup>1</sup> Some of the beds met with in Suffolk in the deep boring at Southwold, under the Norwich Crag, may possibly be of Red Crag age.

<sup>2</sup> M. Mourlon has kindly allowed me to examine the material obtained by the officers of the Belgian Geological Survey from borings in the north of that country, but I have been unable to detect the presence of the Amstelien beds there.

<sup>3</sup> See Godwin-Austen, Quart. Journ. Geol. Soc. vol. vii. (1851) p. 129.

shells in beds of Norwich Crag age seems to show that a river discharged into this bay, and the occasional presence of specimens of *Cyrena fluminalis*, a species now inhabiting the Nile,<sup>1</sup> as well as of mica and Rhenish pebbles, indicates that this river flowed from the south.<sup>2</sup> An interesting indication of the shore-line of the Crag sea occurs at Hoxne, in the Waveney Valley, where, at the most westerly point to which the Norwich Crag has been traced, the Chalk rises suddenly in the form of a cliff.<sup>3</sup>

The enlarged map of East Anglia (Pl. XXXV.) shows the western limit of the area within which exposures of the Norwich Crag are found, and it does not seem probable that the sea of this period extended to any great distance beyond it. Its eastern margin cannot be traced, as in that direction the Crag beds dip below the water-level.<sup>4</sup>

In the typical section of Norwich Crag at Bramerton, there is an upper bed, similar lithologically to the lower one, but containing a rather more boreal fauna, the northern species, *Astarte borealis*, being more common in it, while littoral forms are comparatively, and fluviatile exceedingly, rare. This somewhat more recent and deeper water-bed implies a slight subsidence, and this would have carried the bay farther to the west. Hence, some of the deposits near the margin of the area; or those, like that at Aldeby, from which freshwater shells are absent, or nearly so; or the beds which immediately underlie the Chillesford Clay, may be of the age of the upper rather than of the lower bed at Bramerton. It is difficult, however, to find any marked palæontological difference between the various deposits of the Norwich Crag series, and I have not attempted on the map to distinguish between them.<sup>5</sup>

The Chillesford Clay, the deposition of which followed that of the Norwich Crag, has been from the very first a veritable apple of discord, and the controversies that it has excited have by no means ceased. Mr. H. B. Woodward, studying this formation in the district near Norwich, where it is not well represented, and seems sometimes to be interstratified with other beds, has come to the conclusion that it does not represent any definite geological horizon; but against this, his colleague, Mr. Whitaker, who worked in Suffolk, where such difficulties do not exist, protests. Mr. Clement Reid,

<sup>1</sup> *Cyrena fluminalis* is also found in Thibet and China (S. V. Wood, Jun., Quart. Journ. Geol. Soc. vol. xxxviii. 1882, p. 694) and in some of the rivers of Central Asia.

<sup>2</sup> The presence of land and fluviatile shells, together with Rhenish pebbles, etc., in the Norwich Crag over so large an area as that from Aldeburgh to the Bure Valley, seems to show that the rivers of Central Europe were, at this period, working themselves round to the western side of the Pliocene basin.

<sup>3</sup> See Clement Reid, 'Pliocene Deposits of Britain,' p. 112.

<sup>4</sup> It is much to be regretted that H.M. Geological Survey does not attempt more systematically to clear up doubtful points of this kind by boring. Every square mile of the Belgian Geological Survey maps contains information obtained in this way.

<sup>5</sup> Mr. Wood and I formerly called the Norwich Crag deposits which appeared to be more recent than the lower bed at Bramerton 'Chillesford Crag.' It seems better merely to refer any which can be shown to be so to an upper zone of the Norwich series.

while recognizing the Chillesford Clay as distinct, thinks that it may be equivalent to the Weybourn and Belaugh Crag (referred to below), but the extraordinary abundance of *Tellina balthica* in the latter, and its entire absence from the former, seem to me strongly opposed to that view. At Belaugh and Weybourn more than half the specimens present are those of this species. The Chillesford Clay is not often fossiliferous, but where it is, although other species of *Tellina* commonly occur, this form has never been found.

I am far from thinking that every example of laminated clay in East Anglia should be referred to this horizon. At the same time there are a number of sections of what Mr. Woodward calls 'good Chillesford Clay,' as to which no doubt has ever been expressed, which were originally regarded as such by Sir J. Prestwich, and which were so mapped 25 years ago by Mr. Wood and myself, and since then by different officers of H.M. Geological Survey. These exposures show that the Chillesford Beds are in places nearly 20 feet in thickness, and that they maintain for nearly 70 miles their distinctive character. They seem to me not only to form a definite geological horizon, but to mark a decided change in the geological condition of the Pliocene basin.

The abrupt change, first from the sands of the Norwich Crag, full of drifted and comminuted shells, to the finely laminated micaceous clays of the Chillesford Beds which rest on them, and then to the newer and overlying pebbly gravels is, I think, capable of explanation.

Beds of clay and mud can only originate in quiet water, either at a depth too great to be affected by the movement of tides and currents, or in a position sheltered from their influence. They are especially characteristic of the tidal estuaries of flat countries, being deposited in slack water on the top of the tide, not so much in the channels in which the current flows as upon banks on either side of it, which are alternately covered and uncovered by water. On these the mud quietly settles in the form of films and thin laminae. The character of the sediment may vary with the season. During the floods of winter the water is often turbid with the coarser matter which it contains, while in dry weather the suspended material is of a finer character. It is, moreover, in the higher reaches of the estuary, where the scour is least, that banks of clay principally accumulate; these are eventually raised above the level of the water, and form marshes bordering the stream. Towards the mouth of the valley such beds become intermittent, and the mud is interstratified with sand and gravel.<sup>1</sup>

<sup>1</sup> Shallow-water deposits of clay and silt are not, however, entirely confined to estuaries. Reference should perhaps be made to the alluvium which fringes the eastern margin of Lincolnshire, connecting the estuarine beds of the Humber with those of the Wash, but the destruction of the Holderness coast, which has been so long, and is still, going on, makes it probable that the left bank of the Humber formerly extended farther south than it does at present, so that to some extent the Lincolnshire alluvium may be of estuarine origin. *Scrobicularia piperata*, a species common in muddy estuaries, is characteristic of these beds.

There is no reason to suppose that the Chillesford Clay is a deep-water deposit, but it corresponds very closely with the hypothesis of its estuarine origin. It is composed either of unstratified clay, of a character similar to that of mud produced by inundation, or of fine alternating laminæ of sand and mud, being more clayey and easy to trace in one part of the area, and becoming more sandy, less micaceous, and somewhat more difficult to map in the other. The absence from it of an estuarine fauna has been commented on. It rarely contains shells, however, but when it does they are the shallow-water forms of the Norwich Crag, and of a character not unlike those which may now be found along the banks of the estuaries of Suffolk. The skeleton of a cetacean, 30 feet long, was found at Chillesford, and this may have been brought up by the tide, and stranded at low water. Such an occurrence is by no means infrequent at the present day: *Hyperoodon rostratus* has been taken in the Thames at Barking and Millwall, and the grampus at Battersea, and in the Humber nearly 40 miles from its mouth.

The Chillesford Clay may thus indicate an elevation of the Norfolk area, by which the sandy bay or inlet of the Norwich Crag became land, and a muddy tidal estuary, similar to those of the East of England or of Holland at the present day, but on a larger scale, established itself in East Anglia. Mr. Wood and I formerly believed that this estuary opened to the south, but I now think that the contrary was the case. Mica, which forms the most constant and characteristic feature of these deposits, commonly occurs in the Dutch beds, having been brought down by the Rhine and the Meuse from the Devonian and Carboniferous schists which occur in the region drained by those rivers. Pebbles of white quartz and other rocks similar to those of the Rhenish and Mosean drifts of Holland may be found in the Chillesford Clay, as indeed in all the Pliocene beds of Norfolk.

Although the sea had at this time retired both from Holland and East Anglia, the Rhine must have continued to discharge into the North Sea, and the estuary of the Chillesford Clay may have formed one of the channels by which it did so.<sup>1</sup> It does not seem improbable that the Rhine may have been diverted towards the western side of the Pliocene basin, as a slight subsidence of Suffolk took place at this period, and carried the Chillesford Beds over a district which was dry land during the deposition of the Norwich Crag.

I have shown in the map (Pl. XXXIV.) the possible connexion between the Rhine and East Anglia, but it will be further seen that, if all the exposures of these beds which are recognized as such by the officers of the Survey and myself be taken, they arrange themselves in a sinuous line from Walton-on-the-Naze in Essex to Mundesley on the Cromer coast. I do not wish to press the point too far, but I think that this can hardly be accidental, and that it

<sup>1</sup> In every case where the Rhine is mentioned, it is understood to include the affluents of that river, and especially the Meuse, from which much of the Southern Drift of Holland seems to have been derived.

deserves to be noticed. The Chillesford Beds have no doubt been exposed to considerable denudation; at the same time the dotted lines which I have drawn may indicate approximately a part at least of the tortuous course of this ancient estuary.<sup>1</sup> Beyond these limits there occur in places thin layers of laminated clay, the age of which is doubtful. If these are of Chillesford age they may have been deposited in time of flood beyond the usual channel, or the stream may have changed its course from time to time. It is possible also that the Chillesford Beds may be present below the water-level in some part of East Norfolk, but if so they are the marginal deposit of a wider body of water than that which is suggested on the map, and their supposed boundary to the east must be shifted accordingly. On the whole it seems more probable that the abrupt change from sand to clay, and again from clay to the beds of gravel next to be described, was due to some alteration in the geographical conditions of the East Anglian portion of the Pliocene basin, such as the substitution of an estuary for a bay, rather than to a difference, from some unexplained cause, in the character of the sediment brought into the area.

It is in Norfolk—that is, towards the mouth, as it seems to me, of the supposed estuary of the Chillesford period—that the beds occur upon which Mr. Woodward lays so much stress. In that district cases are occasionally met with where laminated clay is interstratified with sand and gravel, sometimes apparently of Norwich Crag age, but which at other times seem to belong to the later period of the pebbly series. One such case especially occurs to me, that at Hartford Bridge, 2 miles south of Norwich, to which I called Mr. H. B. Woodward's attention and which we visited together many years ago. This was figured by him,<sup>2</sup> but at present it indicates still more plainly the connexion between the Chillesford Clay and the Bure Valley Beds. The section now shows 10 feet of laminated brick-earth, more sandy than the typical Chillesford Clay of Suffolk, interbedded with fine pebbly gravels containing a considerable admixture of stones of southern origin. It seems to me that these beds may belong to a period when the submergence which afterwards carried the sea of the Bure Valley Crag (referred to below) over a considerable part of Norfolk and Suffolk was commencing, but before it had proceeded far enough to put an end altogether to the deposition in places of laminated estuarine beds containing mica brought down from the south. The beds present in the Hartford Bridge section may thus be intermediate between the Chillesford Clay and the Bure Valley Crag, and it is not difficult to understand that there may be others, although it may not be easy to distinguish them, which similarly connect the Chillesford Clay with the Norwich Crag.

Succeeding the Chillesford Clay are some fossiliferous beds of sand and pebbly gravel, composed principally of flint, but containing, as

<sup>1</sup> Estuarine deposits not only imply an estuary, but also indicate the position which it occupied.

<sup>2</sup> Mem. Geol. Surv. Norwich, 1881, pl. iii. fig. 7.

pointed out by Sir J. Prestwich,<sup>1</sup> much southern drift. These occur at Weybourn on the Norfolk coast, at Wroxham and Belaugh in the Bure Valley, and at Crostwick and elsewhere near Norwich. In these appears for the first time, and, as before stated, in great abundance, *Tellina balthica*, a shell unknown from any older horizon of the English Pliocene.<sup>2</sup> They were originally described by Mr. Wood and myself as the Bure Valley Beds, and, with some unfossiliferous gravels which have a considerable development in Norfolk and Suffolk, are shown in our map of the Crag district<sup>3</sup> as the base of the Lower Glacial formation. Sir J. Prestwich afterwards adopted for them the name of 'Westleton Shingle,' including the deposits at Belaugh and other places in the Bure Valley, but excluding that of Weybourn, which he referred to the Norwich Crag. I know of no sufficient reason, however, for such a separation.

The Bure Valley and Weybourn Beds are evidently Pliocene rather than Pleistocene,<sup>4</sup> as pointed out by Messrs. Woodward<sup>5</sup> and Reid,<sup>6</sup> but I think it possible that some of the pebbly gravels associated with them by Mr. Wood and myself may be of Pleistocene age. Considerable difference of opinion exists between the officers of H.M. Geological Survey on this subject. Mr. H. B. Woodward believes that the gravels of Westleton, Henham, Halesworth, and Haddiscoe in the north of Suffolk are glacial, while he regards those of Loddon and Heckingham in the south of Norfolk as of the age of the Crag.<sup>7</sup> Mr. Whitaker does not agree with this view of the case,<sup>8</sup> and my own experience when mapping the district leads me to doubt whether any such division can be traced.

The Bure Valley Beds seem to me to indicate that after the deposition of the Chillesford Clay the sea re-invaded the north-eastern portion of Norfolk and probably of Suffolk, forming a bay into which the Rhine still continued to discharge. Mr. Reid has shown, however, that during the later part of the period represented by the most recent of the Pliocene beds on the Cromer coast, an Arctic climate prevailed, and probably no great interval of time separated them from the Pleistocene era. During the accumulation of these Cromer Beds, as I think the Pliocene deposits newer than the Weybourn Crag might conveniently be called, the sea retired from East Anglia, but it seems to have returned before the deposition of the Lower Glacial Clays, and it may then have re-occupied under

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 477.

<sup>2</sup> For many years some specimens of *Tellina balthica* have been exhibited in the Natural History Museum at South Kensington, labelled 'Postwick,' a Norwich Crag locality, and Sir J. Prestwich gives this species, with a query, from the same place. In both cases Crostwick should be substituted for Postwick. See Trans. Norf. & Norw. Naturalists' Society, vol. ii. p. 377.

<sup>3</sup> Suppl. Crag Moll. vol. iii., Palæont. Soc. 1872.

<sup>4</sup> Messrs. Gunn and Savin discovered the *Tellina balthica*-Crag beneath the freshwater bed at Runton in 1876, Proc. Norw. Geol. Soc. vol. i. p. 50.

<sup>5</sup> 'Geology of England and Wales,' 1876, p. 281.

<sup>6</sup> 'Pliocene Deposits of Britain,' Mem. Geol. Surv. 1890, p. 222.

<sup>7</sup> Mem. Geol. Surv. Norwich, 1881, p. 85. Mr. Woodward's views on the Bure Valley Beds are further given in Geol. Mag. 1882, p. 452.

<sup>8</sup> Mem. Geol. Surv. Southwold, 1887, pp. 25 & 32.

somewhat similar conditions a similar area. If this was so we may perhaps provisionally regard the pebbly gravels of East Anglia as one, though not a strictly continuous formation, the greater part of them being older, while perhaps some of them are newer than the Cromer Beds. It does not seem possible to map them in any other way, as it is almost impossible to distinguish between such deposits. While, therefore, the position of the Weybourn and Bure Valley Crag can be correctly ascertained, all that can be said with certainty as to some of these unfossiliferous gravels is that they are newer than the Chillesford Clay and older than the Contorted Drift.<sup>1</sup>

Sir Joseph Prestwich correlates his Westleton Series with some gravels in the South of England, principally on the ground that they contain pebbles of a similar character. Without expressing any opinion as to the correctness of this view, I may again suggest that this does not necessarily imply that these deposits are synchronous.

No strata equivalent to the Weybourn Crag have been met with in the Dutch borings. *Tellina balthica* occurs in the upper part, but in beds which Dr. Loricé regards as post-Glacial.<sup>2</sup>

The deposition of the Weybourn and Bure Valley Crag was followed by that of the strata which have been so admirably worked out by Mr. Reid, generally known by the unfortunate name of the 'Forest Bed Series.' These deposits, from which so many remains of mammalia have been obtained, are exposed only along the coast, and do not extend to any great distance inland. Consisting of freshwater, estuarine, and marine deposits, they represent a late stage in the Pliocene period, and the final emergence of East Anglia from the Pliocene sea. It is, perhaps, worthy of notice that the south-western margin of the area occupied by these beds is roughly parallel to that of the Chillesford Clay, and the conditions under which the earlier portions of them were deposited may have been similar. From Holland to Norfolk at least the basin of the North Sea had been converted into land, while an estuary occupied a position similar to that of the Chillesford Clay, but somewhat farther to the east. The river which flowed into this estuary came, as did that of the Chillesford Clay, from the south,<sup>3</sup> and brought with it not only the drifted and fragmentary portions of skeletons and teeth of mammalia (principally elephants), including the hippopotamus, and other forms characteristic of a warmer climate than that which obtained generally during the Newer Pliocene period, but also the southern shells *Cyrena fluminalis*, *Hydrobia marginata*,

<sup>1</sup> Mr. H. B. Woodward says that the beds at Westleton are newer than the Lower Glacial Brick-earth.

<sup>2</sup> This species is included in Dr. Loricé's list of fossils from Utrecht, but both Mr. Reid and I have examined the specimens, and think that this is a mistake.

<sup>3</sup> See also Reid, Mem. Geol. Surv. Cromer, 1882, p. 57. This river must have passed over some part of Holland, and at some future time the equivalent of the mammaliferous beds of the Cromer coast may be met with in that country.

and *Lithoglyphus fuscus*.<sup>1</sup> Bones of the musk ox and glutton, animals now confined to northern latitudes, are also found, and indicate possibly more nearly the temperature then prevailing in Norfolk. Many stools of trees such as now inhabit Great Britain occur in the so-called Forest Bed, but these have all been drifted, perhaps some distance, and possibly from the south.<sup>2</sup>

More than once during the deposition of the Cromer Beds the estuary was shifted to the east, and the low-lying land from which the salt water had retired was occupied by fluvial deposits and tenanted by a flora similar, as Mr. Reid has shown, to that of the Norfolk broads at the present day. Once more the sea advanced upon the north-eastern margin of Norfolk, leaving behind it, on its retreat, sands containing the northern shells *Leda myalis* and *Astarte borealis*. These sands again were covered by freshwater beds, in which occur leaves of the Arctic forms *Betula nana* and *Salix polaris*, and this Arctic freshwater bed forms a link connecting the Pliocene with the Pleistocene period.

With the latter a renewed subsidence of Holland commenced, almost equal in importance to that of the Pliocene era, for at Amsterdam the Amstelien is overlain by more than 600 feet of recent and Pleistocene deposits. The relation of the Glacial beds of the Low Countries to those of England presents an interesting and important field of enquiry, but one which cannot be entered upon in this paper. It may perhaps be noticed, however, that no deposits of character similar to that of the Till or Contorted Drift of Norfolk have been met with in the borings here described. In Drenthe, to the N.E. of the Zuiderzee, in the island of Texel, on the coast, and in Urk, beds of hard Till occur which I have not seen, but as to the glacial character of which Dr. Loricé entertains no doubt. Extending somewhat farther to the south there exist, some miles west of Utrecht, steep hills of sand and gravel which seem to be the terminal moraine of the Scandinavian ice-sheet. In a deep railway-cutting which I visited with Dr. Loricé contortions were to be seen closely resembling those of the Norfolk cliffs, and, within the space of a few hundred yards, as many large boulders as could be found at any one time on the beach between Weybourn and Cromer. The south-western limit of the Scandinavian Drift in Holland is marked on the map (Pl. XXXIV.) by a dotted line.

The ice-sheet by which Drenthe and the eastern provinces of Holland were invaded came from the Baltic, and not from Norway, since the erratics found in them are Swedish and not Norwegian. It does not seem that the Scandinavian ice-stream penetrated to the Dutch coast, except in the north as before stated, the

<sup>1</sup> No perfect skeletons occur in the Cromer Beds. With few exceptions (one of which Mr. Reid considers derivative), remains of the larger mammalia are confined to the estuarine deposits.

<sup>2</sup> Mr. Reid, however, has found leaves of the oak, etc., which could hardly have been drifted, in some of the Cromer Beds. The climate of this period seems to me to have been milder than that of the Upper Crag, although glacial conditions may have come on somewhat rapidly towards its close.



Pleistocene deposits of Utrecht and Amsterdam being composed of stratified gravels and sands. It is difficult, therefore, to see how the Baltic glacier could have reached East Anglia, though ice-floes with Scandinavian boulders might easily have done so, while had the Norwegian ice filled the North Sea and overflowed the county of Norfolk, some evidence of its presence ought to be found in the Glacial beds of Holland.

The great thickness of the Amstelien as compared with the Scaldisien strata is perhaps worthy of notice, but whether it may be taken as an indication of the comparative duration of these periods, or only of the comparative amount of sediment brought down by the rivers draining into the Pliocene sea, cannot be decided.

Some of the shells found in the Amstelien beds are not merely British species with a northern range, but boreal forms, which are not now found beyond the limits of the Arctic Circle. The climate of Northern Europe was at that time considerably colder than it is at present, and the glaciers of the mountain districts drained by the Rhine were on a larger scale, with probably a corresponding increase of the sediment brought down by it.<sup>1</sup>

When we attempt to restore in imagination the physical conditions of the Pliocene era in Northern Europe, three features stand out with a certain amount of distinctness: the river Rhine, the basin of the North Sea, and the gradual refrigeration of climate which from the earliest times of the Upper Crag seemed to be heralding the approach of the Glacial epoch.

It has often been said that Holland is the ancient delta of the Rhine, but these borings show that the formation of this delta had commenced as early as the Diestien epoch. During the whole of the Pliocene period, and indeed up to the present day, the rivers of Northern Europe have continued to pour down their sediment, heaping it up on the gradually subsiding bottom of the North Sea. The North Sea basin also, bounded in the first instance on the east by the Miocene deposits of Germany, on the south and west by the older Tertiary and Cretaceous rocks of Belgium and East Anglia, had equally come into existence before the deposition of the Coralline Crag. Since then it has been affected by the great movements of subsidence and elevation which took place during the Glacial and post-Glacial periods. As to the changes of level which occurred during the former, geologists are by no means agreed, but these must have affected the area in question, while in the post-Glacial era the North Sea basin formed at one time a great plain, tenanted by herds of elephants, whose bones and teeth are still dredged by Yarmouth fishermen. During the deposition of the Upper Crag

<sup>1</sup> Swiss geologists maintain that the glaciation of their country commenced in Pliocene times, and that milder conditions of climate intervened between it and the subsequent advance of the ice during the Pleistocene era. See Dr. Preller's paper in *Quart. Journ. Geol. Soc.* vol. li. (1895) p. 369; also Dr. A. Heim, 'Die Geologie der Umgebung von Zürich' (VI. Internat. Geol. Congr. 1894), p. 181. If this was so, this interglacial period may possibly have coincided with the deposition of the earlier portion of the Cromer Beds, which, as we have seen, indicate a climate somewhat milder than that of the Upper Crag.

this basin was filled by the waters of a shallow sea, the boundaries of which travelled now and again in a northerly direction. Its position to-day is similar to that which it occupied during the Scaldisien period, except that it is connected with the S.W. by the Straits of Dover, and that near its western margin have accumulated the Glacial beds of Norfolk and Suffolk, and in its eastern portion material brought into it by the Rhine and the Scandinavian ice.

The hypothesis of a permanent basin with shifting shore-lines seems to be in accordance with all the facts of the case. It affords a possible explanation of the character and disposition of the various Crag beds of the East of England, and enables us to arrange them in order, as members of a continuous and closely-connected series. The western shore of the Newer Pliocene gulf extended at no time far beyond the present English coast, and hence the shallow-water beds of Norfolk and Suffolk, originating at no great distance from the shore, and following from time to time the shifting margin of the sea, give us information as to the various changes which have there taken place in the distribution of land and water. The strata revealed by the Dutch borings, on the contrary, were deposited farther from land and in a subsiding area, and therefore, while they throw no light upon the geographical conditions of the eastern portion of the basin, they afford a vertical sequence of beds representing continuously a considerable portion of the Pliocene epoch. It may be hoped that from this almost unexplored field most important results may hereafter be gained.

The lines which I have drawn to show the possible distribution of land and water during the successive stages of the Crag period must be regarded as only tentative, but even if my suggestions afford no solid and permanent resting-place, they may at least serve as stepping-stones to firmer ground, and to a position whence we may obtain clearer light on some of the problems of the later Tertiary geology of East Anglia.

Lists of the shells obtained from the different Dutch borings, arranged according to the classification adopted in this paper, are given, showing the resemblance of the different faunas to those of the different horizons of the English and Belgian Crag, and the comparative abundance of the different species in each.<sup>1</sup>

These lists, which contain the names of all the species at present known from the Pliocene beds of Holland, are arranged to show at a glance the much closer resemblance between the Amstelien and the Upper Crag than to the Scaldisien or the Walton bed. Two schedules are given: the first containing those species which occur

<sup>1</sup> My best thanks are due to Mr. P. F. Kendall, F.G.S., who, with the late Mr. R. Bell, spent much time and labour in working out the Walton fauna, for allowing me to supplement my own knowledge of this formation by the examination of a list of the Walton mollusca which he is preparing for publication, and also to my good friends in Belgium, Holland, and at Jermyn Street for their courtesy in placing so willingly at my disposal their stores of information.

N.=Norwich Crag only. A.=Amstelian. a.=Arctic.

„ *caput-serpentis*, Linn. .

## PLIOCENE FAUNA (continued).

Schedule I. (continued).																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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PLIOCENE FAUNA (*continued*).

## Schedule II.

	Wood's 'Crag Mollusca.'	Not known living.	Northern.	Southern.	Amstelian.	Red Crag.	Scaldisien, Holland.	Scaldisien, Belgium.	Walton Crag.	Diestien, Holland.	Diestien, Belgium.	Coraline Crag.
<b>Gasteropoda.</b>												
<i>Turritella terebra</i> , Linn. ....	.....	..	..	..	+	+	+	+	+	+	+	+
<i>Calyptræa sinensis</i> , Linn. ....	.....	..	..	+	+	+	+	+	+	+	+	+
<i>Natica Alderi</i> , Forbes .....	.....	..	..	+	+	N.	..	..	..	+	..	+
<i>clausa</i> , Sow. ....	A. ....	..	+	..	+	+	..	..	+	+	..	+
<i>helicina</i> , Broc. ....	.....	+	..	+	+	..	+	?	+	+	..	+
<i>millepunctata</i> , Lam. ....	.....	..	..	+	+	+	+	+	+	+	+	+
<i>Hydrobia ulva</i> , Penn. ....	A. ....	..	..	..	+	N.	..	..	..	..	..	..
<i>Paludestrina terebellata</i> , Nyst .....	( <i>Eulimene</i> )	+	..	..	+	+	..	+	+	..	..	..
<i>Littorina littorea</i> , Linn. ....	A. ....	..	..	..	+	+	..	..	..	..	..	..
<i>Rissoa reticulata</i> , Mont. ....	.....	..	..	..	+	..	..	..	+	..	..	+
<i>Chemnitzia densicostata</i> , Phil. ....	.....	..	..	+	+	..	..	..	+	..	..	+
<i>elegantissima</i> , Mont. ....	<i>C. elegantior</i>	+	..	..	+	+	..	..	+	..	+	+
<i>indistincta</i> , Mont. ....	Wood. ....	..	..	..	+	..	..	..	+	..	..	+
<i>similis</i> , Wood. ....	.....	+	..	..	?	..	..	..	..	+	..	+
<i>Cassidaria bicatenata</i> , Sow. ....	.....	+	..	..	+	+	+	+	+	..	+	+
<i>Buccinum undatum</i> , Linn. ....	.....	..	..	..	+	+	+	+	+	..	+	+
<i>Nassa reticosa</i> , Sow. ....	.....	..	..	..	+	+	+	+	+	+	+	+
<i>Purpura lapillus</i> , Linn. ....	.....	..	..	..	+	+	+	+	+	..	..	..
<i>Fusus elegans</i> , Charl. ....	( <i>Trophon</i> )	+	..	..	+	+	+	+	..	..	..	1 sp.
<i>gracilis</i> , D. & C. ....	.....	..	+	..	+	+	+	+	+	+	?	+
<i>consocialis</i> , Wood. ....	.....	+	..	..	+	+	..	..	+	..	..	+
<i>scalariformis</i> , Gould. ....	A. ....	..	a.	..	+	+	..	..	..	..	..	..
<i>Ringicula ventricosa</i> , Sow. ....	.....	..	..	+	+	+	+	+	..	..	..	+
<i>Pleurotoma clathrata</i> , M. de S. ....	.....	..	..	+	+	..	..	..	..	..	..	+
<i>turricula</i> , Mont. ....	.....	..	+	..	+	+	..	..	+	..	..	..
<i>Cancellaria</i> , sp. ....	.....	..	+	..	+	..	..	..	+	..	..	..
<b>Pelecypoda.</b>												
<i>Ostrea edulis</i> , Linn. ....	.....	..	..	..	..	..	+	+	+	..	..	..
<i>Pecten similis</i> , Laskey .....	.....	..	..	..	..	..	+	..	..	+	..	+
<i>septemradiatus</i> , Müll. ....	<i>P. Danicus</i> , Chem. ....	..	..	..	..	..	..	..	..	+	..	..
<i>Lima subauriculata</i> , Mont. ....	.....	..	..	..	..	..	+	+	..	+	+	+
<i>Limopsis anomala</i> , Eich. ....	<i>L. pygmæa</i> , Wood. ....	..	..	+	..	..	..	+	+	+	+	+
<i>Nucula nucleus</i> , Linn. ....	.....	..	..	..	..	..	+	+	+	+	+	+
<i>Yoldia semistriata</i> , Wood .....	( <i>Leda</i> )	..	..	..	..	..	+	+	..	+	+	+
<i>Cardita corbis</i> , Phil. ....	.....	..	..	+	..	..	+	+	+	+	+	+
<i>chamæformis</i> , Leathes ..	.....	+	..	..	..	..	+	+	+	+	+	+
<i>scalaris</i> , Leathes .....	.....	..	..	+	..	..	+	+	+	+	+	+
<i>senilis</i> , Lam. ....	.....	..	..	+	..	..	+	+	+	+	+	+
<i>Astarte Basterotii</i> , de Laj. ....	.....	+	..	..	..	..	+	+	+	+	+	+
<i>corbuloides</i> , de Laj. ....	.....	+	..	..	..	..	+	+	..	+	+	..
<i>mutabilis</i> , Wood .....	.....	+	..	..	..	..	+	+	..	+	+	..
<i>Omalii</i> , de Laj. ....	.....	+	..	..	..	..	+	+	+	+	+	+
<i>triangularis</i> , Mont. ....	.....	..	..	+	..	..	+	+	+	+	..	+

## PLIOCENE FAUNA (continued).

Schedule II. (continued).		Wood's 'Crag Mollusca.'	Not known living.	Northern.	Southern.	Amstelian.	Red Crag.	Scaldisien, Holland.	Scaldisien, Belgium.	Walton Crag.	Diestien, Holland.	Diestien, Belgium.	Coralline Crag.
Pelecypoda (continued).													
<i>Astarte pygmaea</i> , Münst. ....	.....	.....	+	..	..	..	..	..	+	..	+	..	+
<i>Woodia digitaria</i> , Linn. ....	.....	.....	+	..	+	..	..	+	+	..	+	..	+
„ <i>excurrens</i> , Wood .....	.....	.....	+	..	..	..	..	..	..	..	+	..	+
<i>Diplodonta cf. rotundata</i> , Mont. ....	.....	.....	..	..	+	..	..	+	+	..	+	..	+
<i>Tapes pullastra</i> , Mont. ....	.....	.....	..	..	..	..	..	+	+	+	+	..	+
<i>Tellina compressa</i> , Broc. ....	.....	.....	..	..	+	..	..	+	+	..	+	+	+
<i>Psammobia ferroensis</i> , Chem. ....	.....	.....	..	..	..	..	..	+	+	+	..	..	+
„ <i>vespertina</i> , Chem. ....	.....	.....	..	..	..	..	..	+	+	+	+	..	+
<i>Thracia pubescens</i> , Pult. ....	.....	.....	..	..	+	..	..	+	+	..	..	..	+
Scaphopoda.													
<i>Dentalium cf. dentalis</i> , Linn. ....	.....	.....	..	..	+	..	..	..	+	+	+	+	+
„ <i>entalis</i> , Linn. ....	.....	.....	..	..	..	..	..	..	+	..	+	+	+
Gasteropoda.													
<i>Emarginula fissura</i> , Linn. ....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Trochus cineroides</i> , Wood .....	.....	.....	+	..	..	..	..	..	+	+	+	+	+
„ <i>cf. zizyphinus</i> , Linn. ....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Scalaria clathratula</i> , Adams .....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Turritella incrassata</i> , Sow. ....	.....	.....	..	..	+	..	..	..	+	+	+	+	+
„ <i>turris</i> , Bast. ....	<i>T. triplicata</i> , Broc. ....	.....	..	..	+	..	..	..	+	+	+	+	+
<i>Vermetus intortus</i> , Lam. ....	.....	.....	..	+	..	..	..	..	+	+	+	+	+
<i>Capulus ungaricus</i> , Linn. ....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
„ <i>recurvatus</i> , Wood .....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Natica hemiclausa</i> , Sow. ....	.....	.....	+	..	..	..	..	..	?	+	+	+	+
„ <i>Sowerbyi</i> , Nyst. ....	<i>N. catenoides</i> , Wood. ....	.....	+	..	..	..	..	..	+	+	+	..	+
<i>Rissoa cf. semicostata</i> , Woodw. ...	<i>R. curticostata</i> , Wood. ....	.....	..	+	..	..	..	..	+	+	+	..	+
„ <i>zetlandica</i> , Mont. ....	.....	.....	..	..	..	..	..	..	..	+	+	..	+
<i>Aporrhais pes-pelecani</i> , Linn. ....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Buccinum Dalei</i> , Sow. ....	.....	.....	..	+	..	..	..	..	+	+	+	+	+
<i>Nassa elegans</i> , Leathes .....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Purpura tetragona</i> , Sow. ....	.....	.....	+	..	..	..	..	..	+	+	+	+	+
<i>Fusus alveolatus</i> , Sow. ....	( <i>Trophon</i> ) .....	.....	+	..	..	..	..	..	+	+	+	+	+
„ <i>antiquus</i> , Linn. ....	„ .....	.....	..	+	..	..	..	..	+	+	+	+	+
„ <i>contrarius</i> , Linn. ....	„ .....	.....	..	+	..	..	..	..	+	+	+	+	+
<i>Pleurotoma cancellata</i> , Sow. ....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
„ <i>costata</i> , Da Costa .....	.....	.....	..	..	..	..	..	..	+	+	+	+	+
<i>Ringicula buccinea</i> , Sow. ....	.....	.....	..	+	..	..	..	..	+	+	+	+	+
<i>Bulla umbilicata</i> , Mont. ....	<i>B. conuloides</i> , Wood. ....	.....	..	+	..	..	..	..	+	..	+	+	+

in the Amstelien, the presence of any of them in the lower beds being also marked; and the second, those which are confined to the latter. The more abundant forms are indicated by thicker crosses; those which seem to distinguish the Amstelien are indicated by the letter A. It will be seen that most of these are abundant, and are also common in the Upper Crag, while they are either absent from the Walton bed, or are rarely found in it.

*Synoptical Table of the Pliocene Strata.*

ENGLAND.	BELGIUM.	HOLLAND.
Cromer Beds. (Forest Bed Series).		
Weybourn & Bure Valley Crag.		
Chillesford Clay.		
Norwich Crag.		
Red Crag.		Amstelien.
Walton Crag: Upper bed. Lower bed.	Poederlien. Scaldisien.	Scaldisien.
Coralline Crag. Lenham Crag.	Zone à <i>Isocardia</i> Cor. Diestien Sands.	Diestien.

#### EXPLANATION OF PLATES XXXIV. & XXXV.

##### PLATE XXXIV.

Map to illustrate the possible distribution of land and water in the Anglo-Dutch Area during the various stages of the Pliocene Period.

##### PLATE XXXV.

Map of the Crag District, on the scale of 4 miles to the inch.

#### DISCUSSION.

Mr. CLEMENT REID agreed that the dominant factor in Newer Pliocene geography was the folding which raised an east-and-west barrier across the South of England and Belgium, gradually forced northward the Pliocene sea and the estuary of the Rhine, and caused the accumulation in Holland of an enormous thickness of shallow-water deposits. He suggested that the 'Amstelien' may fill the gap between our Walton and Butley Crag, for the fauna is scarcely as Arctic as that of the Butley Crag. The evidence seems, however, hardly sufficient to settle this point.

Mr. H. B. WOODWARD referred to the excellent geological map of Norfolk made by Mr. Harmer before the official Geological Survey was commenced, and remarked that the Chillesford Clay had been one of the chief sources of dispute. While working in the Norwich area he had found no persistent divisions in the group which included the Fluvio-marine Crag, the Chillesford shell-bed, the Chillesford Clay, and the Bure Valley Beds, and he had grouped them under the general term Norwich Crag Series. He was therefore glad that Mr. Harmer now agreed that the beds belonged to one formation; and if it were desirable to use a term that should correspond with the other group-names used by the Author, he would suggest that the old term 'Icenian' be used for this Norwich Crag Series. He was disposed to agree with Mr. Harmer's general conclusions with regard to the Chillesford Clay, and thought that now there were no serious differences of opinion between them; the Author in fact had done much to harmonize a subject which before was full of discord.

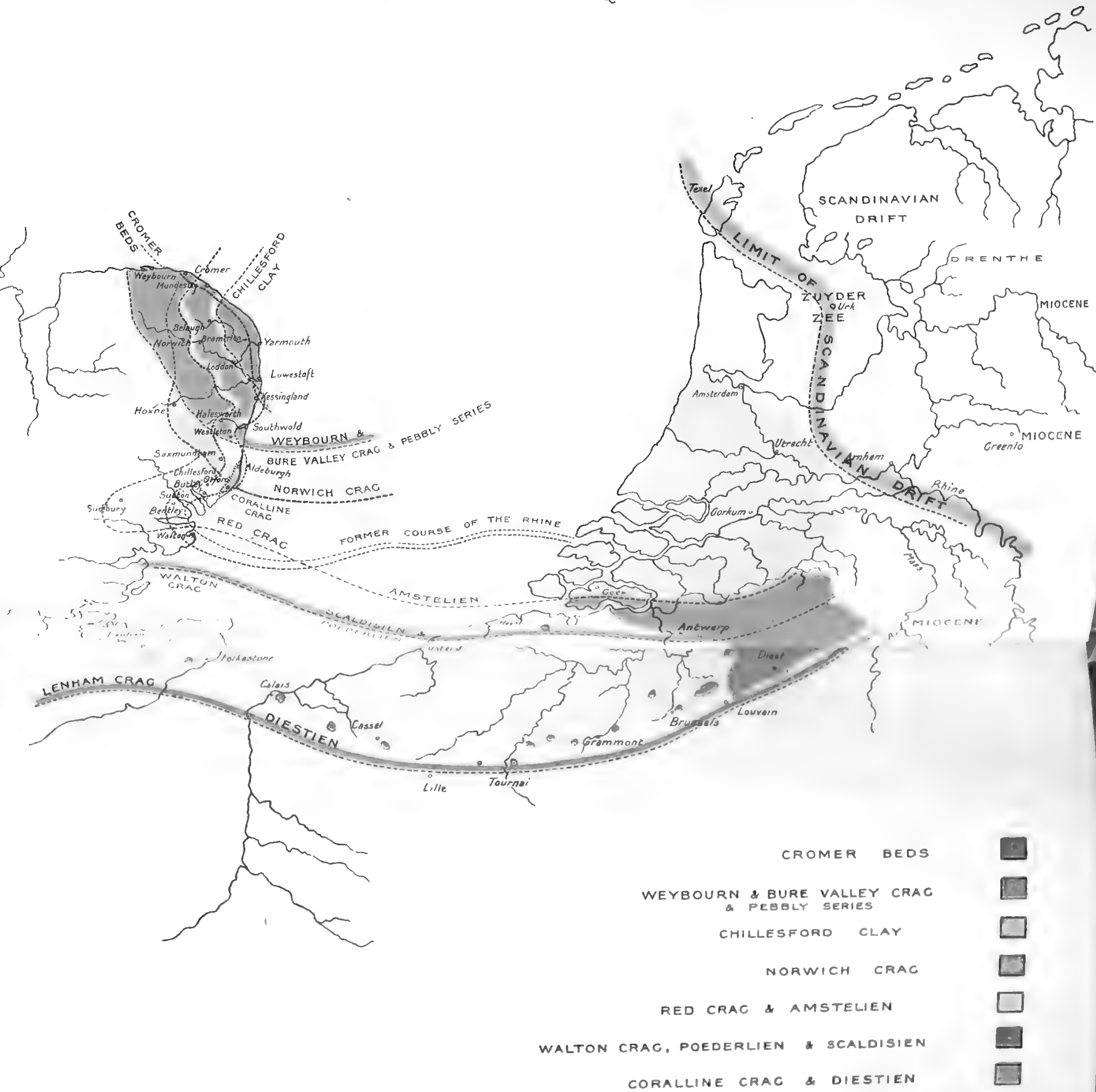
Mr. W. J. LEWIS ABBOTT said that he had long since come to the conclusion that we must know considerably more about Tertiary Holland and Belgium before we can know the correct history of the Weald. His closer studies of the latter had suggested hypothetical conditions in these countries, which this valuable paper would show to actually exist. The Lenham Beds might be shown to extend a little south of the position indicated on the map, and very much farther west. About Lenham the casts of fossils in the ironstone are not rare, but they quickly decrease as we travel westward. We note, however, the incoming of flint-pebbles in a soft white condition. By the help of these ironstones and the gradually altering nature of the sands we can trace the Lenham Beds into Surrey. It was the southerly elevation and north-easterly depression that subsequently raised the Lenham sea-bed to hillsides, and it was the rivers which flowed down these in later Crag times that deposited the Plateau-gravels in which are found the first evidences of artificially-worked flints.

The AUTHOR replied, thanking the Fellows for the reception accorded to his paper.







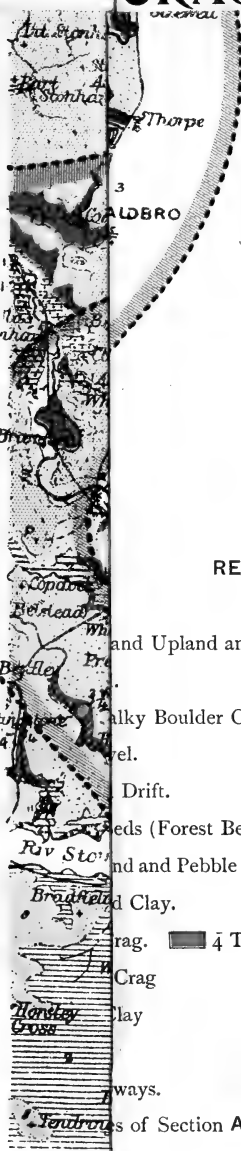


MAP to illustrate the possible DISTRIBUTION of LAND & WATER in the ANGLO-DUTCH area, during the various stages of the PLIOCENE period.






# THE CRAG DISTRICT,

*deposited.*



## REFERENCE TO THE MAP.

- and Upland and Lowland Brickearths (Post Glacial).
- alky Boulder Clay. (Upper Glacial.)
- el. (Middle Glacial.)
- Drift. (Lower Glacial.)
- eds (Forest Bed Series.)
- nd and Pebble Beds, and Weybourn and Bure Valley Crag. (Newer Pliocene)
- nd Clay. (Older Pliocene.)
- rag.  4 The Red Crag.  4 The Norwich Crag.
- Crag
- lay
- ways.  Well Borings.
- ds of Section A to W. (See "Supplement to Crag Mollusca.")
- ds.

of the principal Parish Church of the places named. The position is thus shown, but in some few places where the shading is intricate omitted.



# THE CRAG DISTRICT,

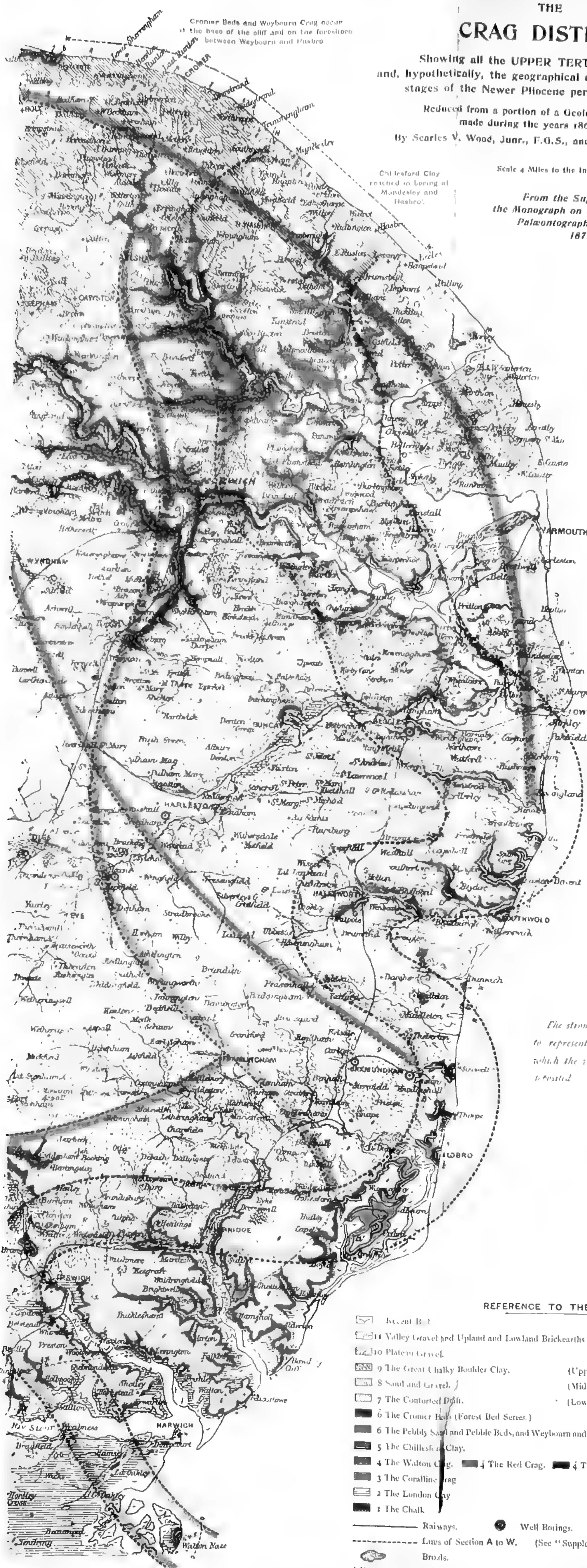
Showing all the UPPER TERTIARY formations and, hypothetically, the geographical conditions of the various stages of the Newer Pliocene period in East Anglia.

Reduced from a portion of a Geological Survey Map made during the years 1864 to 1872.

By Seales V. Wood, Junr., F.O.S., and F. W. Harmer, F.G.S.

Scale 4 Miles to the Inch.

From the Supplement to the Monograph on the Crag Mollusca Palaeontographical Society, 1872.



Cromer B. 15 and Chillesford Clay shown in cliff section between Pakefield and Kessing and

The strong coloured lines are intended to represent the possible limits within which the various beds were originally deposited

## REFERENCE TO THE MAP.

- Recent Bed
- 11 Valley Gravel and Upland and Lowland Brickearths (Post Glacial).
- 10 Plateau Gravel.
- 9 The Great Chalky Boulder Clay. (Upper Glacial.)
- 8 Sand and Gravel. (Middle Glacial.)
- 7 The Contorted Drift. (Lower Glacial.)
- 6 The Cromer Beds (Forest Bed Series)
- 6 The Pebbly Sand and Pebble Beds, and Weybourn and Bure Valley Crag. (Newer Pliocene)
- 5 The Chillesford Clay.
- 4 The Walton Crag. 4 The Red Crag. 4 The Norwich Crag. (Older Pliocene.)
- 3 The Conalline Crag
- 2 The London Clay
- 1 The Chalk
- Railways.
- Well Borings.
- Lines of Section A to W. (See "Supplement to Crag Mollusca.")
- Broads.

+ Denotes the position of the principal Parish Church of the places named. The position of every Parish Church is thus shown, but in some few places where the shading is intricate the names have been omitted.  
7 Denotes a Hamlet.





# GENERAL INDEX

TO

## THE QUARTERLY JOURNAL

AND

### PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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PROCEEDINGS  
OF THE  
GEOLOGICAL SOCIETY OF LONDON.

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SESSION 1895-96.

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November 6th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Samuel John Truscott, Esq., Assoc.R.S.M., P.O. Box 590, Johannesburg, Transvaal, South Africa, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced that the Council had temporarily appointed Mr. Clyde H. Black to the post of Assistant-Clerk.

The following communications were read :—

1. 'The Serpentine, Gneissoid, and Hornblendic Rocks of the Lizard District.' By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in University College, London.

2. 'The "Schistes Lustrés" of Mont Jovet (Savoy).' By J. W. Gregory, D.Sc., F.G.S.

The following specimens, etc., were exhibited :—

Rock-specimens and microscope-slides, exhibited by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., in illustration of his paper.

Rock-specimens and microscope-slides, exhibited by Dr. J. W. Gregory, F.G.S., in illustration of his paper.

Specimen of a Lithistid Sponge from the Upper Chalk, found in  
VOL. LII. a

Flint Gravel at Croydon, and exhibited by W. F. Stanley, Esq., F.G.S., F.R.A.S.

Book of Photographs of Gohna Lake (Kumáun, Himalayas), before and after flood, exhibited by Dr. W. T. Blanford, F.R.S., Treas.G.S., on behalf of C. L. Griesbach, Esq., C.I.E., Director of the Geological Survey of India.

Photographs illustrating structures in the 'Granulitic Series'; and structures produced by deforming heterogeneous masses of Clay, exhibited by J. J. H. Teall, Esq., M.A., F.R.S., Sec.G.S.

Maxilla of *Portheus*, from the Lower Chalk of Burham; and *Synhelia Sharpeana*, from the Upper Chalk of Croydon, exhibited by G. E. Dibley, Esq., F.G.S.

Sheets 9 and 13 of the Geological Survey Index Map (Scale, 1 inch=4 miles), presented by the Director-General of that Survey.

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November 20th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

The Rev. Henry Arthur Hall, M.A., The Schoolhouse, Totnes, South Devon, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Additional Notes on the Tarns of Lakeland.' By J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.

2. 'Notes on the Glacial Geology of Arctic Europe and its Islands.—Part I. Kolguev Island.' By Col. H. W. Feilden, F.G.S.; with a 'Report on the Erratic Boulders from the Kolguev Beds,' by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

The following specimens, etc., were exhibited:—

Rock-specimens, plant- and other fossil remains from Kolguev Island, exhibited by Col. H. W. Feilden, F.G.S., in illustration of his paper.

Photograph of Mud Cracks (scale  $\frac{1}{6}$ ) in Coal Measure mine-refuse mud at foot of spoil-bank, No. 1 Mine, Spring Valley (Illinois), U.S.A., exhibited by W. S. Gresley, Esq., F.G.S.

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December 4th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Samuel C. Barlow, Esq., Roman Road, Stockport; William Boulton, Esq., A.R.C.S., Lecturer on Geology and Physiography in the Mason College, Birmingham; William John Prinsep Burton, Esq., Lea, Matlock Bath; the Rev. Henry Canham, LL.B. Cantab., Leathley Rectory, Otley; Allan Greenwell, Esq., Blyth House, Frome, Somerset; Karl Grossmann, M.D., F.R.C.S., 70 Rodney Street, Liverpool; James Henry Hosking, Esq., Helred, Enfield; Edward Alfred Martin, Esq., 69 Bensham Manor Road, Thornton Heath; Thomas Murdoch, Esq., J.P., Argentine Consul, Dundee; John Parkinson, Esq., 251 Camden Road, N.; Malcolm Paterson, Esq., M.Inst.C.E., 35 Manor Row, Bradford, Yorkshire; Walter George Ridewood, Esq., 80 Oakley Street, Chelsea, S.W.; R. W. Boothman Roberts, Esq., 63 Carisbrooke Road, Walton, Liverpool; and the Rev. E. Adrian Woodruffe-Peacock, Cadney Vicarage, Brigg, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Alteration of certain Basic Eruptive Rocks from Brent Tor, Devon.' By Frank Rutley, Esq., F.G.S.
2. 'The Mollusca of the Chalk Rock.—Part I.' By Henry Woods, Esq., M.A., F.G.S.

The following specimens, etc., were exhibited:—

Specimens and microscope-sections exhibited by Frank Rutley, Esq., F.G.S., in illustration of his paper.

Drawings of Cretaceous Mollusca, exhibited by H. Woods, Esq., M.A., F.G.S., in illustration of his paper.

Geological Survey of England and Wales, Vertical Sections: Sheet 80, by A. Strahan, Esq., M.A., F.G.S., presented by the Director-General of H.M. Geological Survey.

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December 18th, 1895.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

William Valentine Ball, Esq., B.A., King's College, Cambridge; Edward Philip Binet, Esq., Assoc.M.Inst.C.E., 100 Victoria Street, Westminster, S.W.; Richard Herbert Lapage, Esq., M.Inst.C.E.,

Oakfield, Langley Avenue, Surbiton ; W. T. Tucker, Esq., Parkside, Loughborough, Leicestershire ; David John Williams, Esq., Science Master, County and Technical School, Narberth, South Wales ; and Francis Wood, Esq., M.Inst.C.E., 8 Bond Terrace, Wakefield, Yorks., were elected Fellows ; Prof. G. K. Gilbert, Washington, D.C., was elected a Foreign Member ; and Dr. A. Penck, Vienna, was elected a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

Mr. H. B. WOODWARD called the attention of the Society to advance copies of certain maps exhibited by the Director-General of the Geological Survey.

The following communications were read :—

1. 'The Tertiary Basalt-plateaux of North-western Europe.' By Sir Archibald Geikie, D.Sc., LL.D., F.R.S.

2. 'The British Silurian Species of *Acidaspis*.' By Philip Lake, Esq., M.A., F.G.S.

The following objects were exhibited :—

A series of specimens and microscopic slides illustrating the rocks of the Inner Hebrides and St. Kilda ; and a collection of photographs, sketches, diagrams, and maps, depicting the geological structure of these islands and the Farøe Isles, also a MS. geological map (6-inch scale) of the island of Canna. Exhibited by Sir Archibald Geikie, D.Sc., LL.D., F.R.S., in illustration of his paper.

Specimens of *Acidaspis*, some exhibited by Philip Lake, Esq., M.A., F.G.S., in illustration of his paper, and others exhibited by the Director-General of H.M. Geological Survey, in illustration of the same paper.

Advance copies of the Geological Survey Index Map, Sheet 11, and of a new edition (printed in colours) of Sheet 12 ; copies of Sheet 249 (Drift and Solid), being the first map of the New Survey of the South Wales Coal-field ; also a MS. copy of Sheet 81 (Raasay and portion of Skye). Exhibited by the Director-General of H.M. Geological Survey.

Sheet 341, New Series, 1-inch map (with Drift), West Fleet (Dorset). By A. Strahan, 1895. Presented by the Director-General of H.M. Geological Survey.

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January 8th, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

George William Colenutt, Esq., Hanway Lodge, Belvedere Street, Ryde; and John Collett Moulden, Esq., A.R.S.M., College Park, Adelaide, South Australia, were elected Fellows of the Society.

The following Fellows, nominated by the Council, were elected Auditors of the Society's accounts for the preceding year:—BENNETT H. BROUGH, Esq., and R. S. HERRIES, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. 'A Delimitation of the Cenomanian, being a Comparison of the Corresponding Beds in Southern England and Western France.' By A. J. Jukes-Browne, Esq., B.A., F.G.S., and William Hill, Esq., F.G.S.

2. 'The Llandovery and Associated Rocks of Conway.' By G. L. Elles and E. M. R. Wood, Newnham College. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.)

3. 'The Gypsum Deposits of Nottinghamshire and Derbyshire.' By A. T. Metcalfe, Esq., F.G.S.

The following specimens were exhibited:—

Fossils, rock-specimens, and microscope-sections, exhibited by A. J. Jukes-Browne, Esq., B.A., F.G.S., and William Hill, Esq., F.G.S., in illustration of their paper.

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January 22nd, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Harry Graves, Esq., B.A. Oxon., 5 St. Oswald's Road, West Kensington, W.; A. W. Rogers, Esq., B.A., Christ's College, Cambridge; Alfred John Saise, Esq., C.E., Ventnor House, Fishponds, Bristol; and Lionel Leigh Smith, Esq., B.A. Cantab., Crowham Manor, Westfield, Battle, Sussex, were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. W. W. WATTS, in the absence of Prof. Lapworth, called attention to three specimens of sandstone and limestone containing specimens of some species of *Hyolithes*, which Prof. Lapworth had found in the higher part of the Cambrian quartzite at Nuneaton, in Warwickshire. Three of the species recognized (*Hyolithes princeps*, *Coleoloides typicalis*, and *Stenotheca rugosa*) occur in the *Olenellus*-beds of America, and three others, *Torrellella lævigata*, *Hyolithes* (*Orthotheca*) *corneolus*, and *H. de Geeri*, in the same rocks in Europe. The *Olenellus*-zone of Nuneaton occurs above the main mass of the quartzite and below the Stockingford Shales, in a series of rocks only recently exposed by quarrying.

The following communications were read :—

1. 'On the Speeton Series in Yorkshire and Lincolnshire.' By G. W. Lamplugh, Esq., F.G.S.

2. 'On some Podophthalmatous Crustacea from the Cretaceous Formation of Vancouver and Queen Charlotte Islands.' By Henry Woodward, LL.D., F.R.S., P.G.S.

3. 'On a fossil Octopus, *Calais Newboldii* (J. de C. Sby., MS.), from the Cretaceous of the Lebanon.' By Henry Woodward, LL.D., F.R.S., P.G.S.

4. 'On Transported Boulder Clay.' By the Rev. Edwin Hill, M.A., F.G.S.

The following specimens were exhibited :—

Fossils from the Speeton Series in Yorkshire and Lincolnshire, with a microscope-section of a so-called 'derivative pebble' from the nodular bed at the base of the Spilsby Sandstone, exhibited by G. W. Lamplugh, Esq., F.G.S., in illustration of his paper.

Specimens of *Callianassa Whiteavesii*, *Homalopsis Richardsoni*, and *Plagiolophus vancouverensis*, from the Geological Survey of Canada, with two of the latter from the Society's Museum, exhibited by Dr. Henry Woodward, F.R.S., P.G.S., in illustration of his first paper.

A specimen of *Calais Newboldii*, from the Cretaceous of the Lebanon, from the Society's Museum, exhibited by Dr. Henry Woodward, F.R.S., P.G.S., in illustration of his second paper.

Specimens of *Hyolithes*-sandstone (*Olenellus*-zone) recently discovered at Nuneaton, exhibited by Prof. Charles Lapworth, LL.D., F.R.S., F.G.S.

February 5th, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

Colonel Charles Kendal Bushe, Bramhope, Blackheath Road, Old Charlton, Kent, and John Turner, Esq., Donisthorpe, Ashby-de-la-Zouch, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On the Morte Slates and Associated Beds in North Devon and West Somerset.—Part I.' By Henry Hicks, M.D., F.R.S., F.G.S.

2. 'Evidences of Glacial Action in Australia in Permo-Carboniferous Time.' By Prof. T. W. Edgeworth David, B.A., F.G.S.

The following specimens, maps, and photographs were exhibited :—

Fossils exhibited by Dr. Henry Hicks, F.R.S., F.G.S., in illustration of his paper.

Fossils from North Devon, exhibited by the Rev. H. H. Winwood, M.A., F.G.S.; and specimens of Graptolites, exhibited by John Hopkinson, Esq., F.G.S., in illustration of Dr. Hicks's paper.

Glaciated boulders, and photographs of the same, exhibited by Prof. T. W. Edgeworth David, B.A., F.G.S., in illustration of his paper.

Fragment of Boulder from the Carboniferous Boulder Bed of the Panjāb Salt-Range, collected by Dr. H. Warth, exhibited by Dr. W. T. Blanford, F.R.S., Treas.G.S.

Australian auriferous specimens, exhibited by the President on behalf of J. C. F. Johnson, Esq., of South Australia.

Sheets 20, 21, 26, and 27 of the 1-inch Map with MS. geological work by W. A. E. Ussher, Esq., F.G.S., exhibited by the Director-General of H.M. Geological Survey.

Photograph of the late Martin Simpson, presented by Arthur Smith Woodward, Esq., F.L.S., F.G.S.

## *ANNUAL GENERAL MEETING,*

February 21st, 1896.

Dr. HENRY WOODWARD, F.R.S., President, in the Chair.

### REPORT OF THE COUNCIL FOR 1895.

THE continued prosperity of the Society from the financial point of view must again form a subject of congratulation, and the Council have the additional pleasure of pointing out that the decrease which had been noticeable in the number of Fellows, mentioned in the three previous Annual Reports, has now been all but arrested, the actual decrease in the total number of Fellows announced this year being only 1, as compared with 11 in 1894, and 46 in 1893.

During 1895 the total number of Fellows elected into the Society was 43, of whom 32 paid their fees before the end of that year. Moreover, fees were received from 12 previously elected Fellows, and thus the total accession of new Fellows amounts to 44 during the twelvemonth.

There was, on the other hand, a total loss of 45 Fellows during the year 1895—25 by death, 10 by resignation, and 10 removed from the list because of non-payment of their Annual Contributions.

The actual decrease in the total number of Fellows is, therefore, as above stated, 1.

Of the 25 Fellows deceased, 9 were Compounders, 10 were Contributing Fellows, and 6 were non-Contributing Fellows.

On the other hand, 9 Fellows compounded during the past year for their Annual Contributions. The total accession of Contributing Fellows is thus seen to be 35, and the total loss being 30 ( $10+10+10$ ), the increase in the number of Contributing Fellows is 5.

At the end of 1894 the Council reported one vacancy in the List of Foreign Correspondents. In 1895, 4 Foreign Members and 1 Foreign Correspondent died. The vacancies which thus arose were partly filled by the election of 3 Foreign Members and 3 Foreign



Correspondents during the past year; but at the end of 1895 there was still 1 vacancy in the List of Foreign Members, and 2 vacancies in the List of Foreign Correspondents.

The total number of Fellows, Foreign Members, and Foreign Correspondents, which at the end of 1894 was 1321, stood at 1318 on December 31st, 1895.

The Society's Income and Expenditure in the year under review may be summarized as follows:—

The total Receipts amounted to £3249 13s. 4d., being £666 7s. more than the estimated Income for 1895. On the other hand, the total Expenditure during that year amounted to £2398 5s. 11d., being less by £181 10s. 1d. than the estimated Expenditure for 1895. The actual excess of Receipts over current Expenditure in that year was £492 18s. 4d.

It should be mentioned here that the following Re-investment of a portion of the Society's Funds was made in 1895. Of  $2\frac{3}{4}$  per Cent. Consolidated Stock £3769 2s. 6d. was sold at  $104\frac{3}{8}$ , and the sum thus produced was applied to the purchase of £2000 India 3 per Cent. Stock at 104, and £1295 Midland Railway 4 per Cent. Perpetual Preference Stock at  $141\frac{1}{2}$ . Moreover, in the various Trust Funds held by the Society, the following Re-investments were made. On account of the Wollaston Fund £1084 1s. 1d.  $2\frac{3}{4}$  per Cent. Consolidated Stock was sold at  $104\frac{5}{8}$ , and the sum thus obtained was applied to the purchase of £1073 Hampshire County 3 per Cent. Stock at  $105\frac{5}{8}$ . Similarly, the £500  $2\frac{3}{4}$  per Cent. Consolidated Stock belonging to the Barlow-Jameson Fund was sold at  $104\frac{5}{8}$ , while £468 Great Northern Railway 3 per Cent. Debenture Stock was purchased in lieu of it at  $110\frac{5}{8}$ ; also £209 8s. 6d.  $2\frac{3}{4}$  per Cent. Consolidated Stock forming the Bigsby Fund was sold at  $104\frac{5}{8}$ , and the sum thus obtained was applied to the purchase of £210 Cardiff Corporation 3 per Cent. Stock at  $104\frac{1}{2}$ . It need hardly be pointed out that the object of these Re-investments was to obtain a larger Income while still holding perfectly sound securities.

The Council have pleasure in announcing the completion of Volume LI. of the Society's Quarterly Journal and the commencement of Volume LII.

The first number of the new Record of Geological Literature added to the Society's Library was issued concurrently with the May number of the Journal in 1895, and its usefulness seems to have been very generally recognized. As was stated in the previous Report of the Council, now and in future this publication will appear concurrently with the February number of the Society's Quarterly Journal.

The compilation of the Index to the first Fifty Volumes of the Quarterly Journal is now all but complete, Vol. 48 having been reached, and the manuscript will very soon be placed in the hands of the printers. It is confidently hoped that the whole of the Index will be placed in the Fellows' hands in the course of the present year.

The question as to how far it is desirable for the Society to maintain a Museum has, for a considerable time, been under the earnest consideration of the Council, and it was felt that if the Society decided that the maintenance of the collections in their present condition was undesirable, the British Museum (Natural History) would probably be the most satisfactory receptacle for them. The Council have accordingly been in communication with the Trustees of the British Museum, and find that they would be willing to receive such portions of the collections as the Society may wish to transfer to them on the following conditions:—The specimens which are types and those which illustrate papers read before the Society are to be preserved and maintained apart, and the Trustees will reimburse the Society for the expenses in connexion with the transference up to a sum not exceeding £300.

The provisional assent of the Trustees of the British Museum to these conditions was formally given at their meeting of January 25th, 1896; and as the ultimate decision regarding the proposed transference must rest with the general body of Fellows, the subject will no doubt be brought forward at a Special General Meeting at an early date.

Meanwhile, a short summary of the steps taken in connexion with the Museum may here be brought to the notice of the Fellows.

On April 22nd, 1891, the attention of the Council having been drawn by the Rev. J. F. Blake to the unsatisfactory state of the Society's Museum, as regards defective labelling, incomplete registration, bad conditions of location and preservation of specimens, etc., a Special Committee was appointed to examine into the question. On May 27th, that Committee finally reported to the effect that it was desirable to select and register all specimens illustrating the history of the Society (including type-specimens), and called attention to collections of simple minerals, typical foreign rocks, and recent shells, with a view to their possible removal. This report was adopted by the Council the same day (May 27th, 1891), and Mr. C. Davies Sherborn, F.G.S., was afterwards requested to undertake the work of registration of important specimens thus selected. This task Mr. Sherborn proceeded with as rapidly as the state of his health would allow. He completed it, so far as the English Collections were concerned, and, by the end of 1895, had gone through part of the Foreign Collection, having, in all, examined about three-fifths of the Society's Museum.

An epitome of the contents of the Museum and a statement of the work accomplished were laid before a Special Committee on October 29th, 1895, and that Committee reported on November 6th to the Council, recommending the transference of the Museum to the National Collections on the conditions already cited, reserving to the Society such specimens of historical interest or of an ornamental nature as are displayed on the walls of the Society's Apartments. This Report was, after careful consideration, adopted by the Council on November 20th, 1895.

If the Society decide upon the transference, the space, when vacated by the collections, would become available for the Library; and the Council must point out that the provision of further accommodation for books will soon become a matter of urgent necessity. As it is, the proper and commodious arrangement of many of the serial publications is hampered for want of room.

The Council are of opinion that the Redecoration of the Society's Apartments and the introduction of the Electric Light constitute improvements which it is desirable to carry out at an early date. The total cost would probably amount to between £700 and £800, and the Balance Sheet placed in the hands of the Fellows shows that the necessary expenditure could be almost entirely provided for from the surplus that has accrued during the last few years. At the same time, the expense of only a portion of the necessary Redecoration is included with that of the Electric Installation in the Estimates for the current year, so that the whole expenditure may be spread over a period of not less than two years.

The following awards of Medals and Funds have been made by the Council:—

The Wollaston Medal is awarded to Prof. Eduard Suess, For. Memb. G.S., of Vienna, in recognition of his long and brilliant services to the cause of Geological Science.

The Murchison Medal, with a sum of Ten Guineas, is awarded to Mr. T. Mellard Reade, F.G.S., in recognition of the value of his work on mountain-making, Glacial drifts, and other branches of post-Pliocene geology.

The Lyell Medal, with a sum of Twenty-five Pounds, is awarded to Mr. Arthur Smith Woodward, F.G.S., in recognition of the value of his work on Fossil Vertebrata, and especially in Palæichthyology.

The Balance of the Proceeds of the Wollaston Fund (together with a sum of Six Pounds Fifteen Shillings transferred from the Barlow-Jameson Fund, in order to supplement an accidental deficiency in the Wollaston Fund incidental to the aforementioned change of investments) is awarded to Mr. Alfred Harker, in testimony of appreciation of his petrological work, and with the view of assisting him in further research.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mr. Philip Lake, F.G.S., as a recognition of the value of his palæontological and other researches amongst the older rocks, and to aid him in the prosecution of these studies.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Dr. W. F. Hume, F.G.S., for his researches on Cretaceous rocks and on the Loess formation, and also to assist him in further work.

The other moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Charles W. Andrews, F.G.S., in recognition of the value of his work on Fossil Birds and Reptilia, and to assist him in the prosecution of further investigations.

An award of Twenty Pounds is made from the Barlow-Jameson Fund to Mr. Joseph Wright, F.G.S., in token of appreciation of his

work on the microfauna of the Irish Chalk, and with the view of aiding him in further research.

Another award of Twenty Pounds from the Barlow-Jameson Fund is made to Mr. John Storrie, of Cardiff, as a mark of appreciation of his original work on the geology of the neighbourhood of that town, and to assist him in carrying out further useful investigations.

The Council cannot conclude this Report without referring to the loss which the Society has sustained in the person of its valued and most efficient Assistant-Clerk, Mr. Francis E. Brown, who died suddenly in the beginning of August last. He had served the Society for upwards of nine years, and had earned the esteem and confidence, not only of the Officers and Council, but of all those among the Fellows who came into contact with him.

#### REPORT OF THE LIBRARY COMMITTEE FOR 1895.

Your Committee have pleasure in stating that very many valuable additions have been made to the Library during the past year, both by Donation and Purchase. It is, in a large measure, due to the liberality of the Fellows, of various public bodies, and of kindred societies, that the donations far exceed in amount the purchases: this will be readily deduced from the statistics embodied in the present Report.

By Donation the Library has received about 85 Volumes of separately published works, 377 Pamphlets and detached Parts of works, 172 Volumes and 207 detached Parts of serial publications (Transactions, Memoirs, Proceedings, etc.), and 16 Volumes of Newspapers. The total addition to the Library by Donation amounts therefore to 273 Volumes, 377 Pamphlets, and 207 detached Parts. Moreover, 116 Sheets of Maps have been presented to the Society during the past year.

Your Committee desire to call special attention to the magnificent Geologic Atlas of the United States, all the sheets of which (so far as published) have been presented by the Government of that country. Nor have other public bodies in the United States failed in their wonted liberality: among others, the New York, Minnesota, Missouri, and Alabama State Geological Surveys have enriched this Society's Library with many handsome volumes of memoirs, plates, and maps. Three important volumes of the *Beiträge zur geologischen Karte der Schweiz* have been received from the Swiss Geological Commission during the past year, as also a large number of maps from the Geological Survey of the kingdom of Saxony. No less than twenty-four sheets of maps have been presented by the Geological Survey of Canada, and six volumes of memoirs by the *Comité Géologique* of St. Petersburg. From H.M. Geological Survey have come some important memoirs and several sheets of the 1-inch map (both drift and solid geology) and sheets of horizontal and vertical sections; while from H.M. Treasury the Society has received the volume embracing the Summary of the Scientific Results of the

'Challenger' Expedition. The first instalment of the International Geological Map of Europe (including seven sheets) has also been received, and from the Geological Survey of India has come the 2nd edition of the small-scale geological map of that Empire.

A valuable collection of geological papers, many of which are now out of print, has been presented by Prof. G. J. Allman, F.R.S. Monsieur P. de Lorient-Lefort, For. Corr. G.S., of Geneva, Señor Don Florentino Ameghino, of Buenos Ayres, and the Marchese A. de Gregorio, of Palermo, have respectively enriched the Library with sets of their own papers and memoirs; and the Royal University of Upsala, besides presenting the 'Meddelanden' published by its Geological Institute, has sent through its Librarian a considerable number of separately printed papers by Scandinavian geologists.

The Society's collection of portraits of historical interest has been enriched by the presentation of a drawing in crayons of Leonard Horner, given by Mrs. Katherine Lyell, and a photograph of the well-known Yorkshire geologist, Martin Simpson, given by Mr. Arthur Smith Woodward. Moreover, a portrait in oils of the late Dean Buckland has been purchased from his daughter, Mrs. Gordon.

The Books, Maps, and Portraits enumerated above were the gift of 191 Personal Donors, 62 Public Bodies, and 200 Societies and Editors of Periodicals.

The Purchases made on the recommendation of the Standing Library Committee amounted to 36 Volumes and 15 Parts of separately published works, 25 Volumes and 20 Parts of works published serially, and 10 Sheets of Maps.

The total amount expended upon the Library during the year 1895 is as follows:—

	£	s.	d.
Books, Periodicals, etc., purchased . . . . .	68	7	5
Binding of Books and Mounting of Maps . . . .	99	1	10
Part cost of preparing Map Catalogue . . . . .	3	11	3
	<hr/>		
	£171	0	6
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Your Committee have pleasure in announcing that the manuscript Card Catalogue of the Geological Maps and Sections in the Library is now practically completed.

As the question of the Museum has been dealt with by a Special Committee who have reported to the Council, all that need be said in this place is that the sum set apart in the Estimates, for registering and cataloguing specimens, namely £50, has been expended during the past year, and constitutes the sole item of expenditure incurred in connexion with the Museum in 1895.

The following Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the past year:—

# I. GOVERNMENT DEPARTMENTS AND OTHER PUBLIC BODIES.

- Alabama.—Geological Survey of Alabama. Montgomery (Ala.).  
 American Museum of Natural History. New York.  
 Austria.—Kaiserlich-Königliche Geologische Reichsanstalt. Vienna.  
 —. Kaiserlich-Königliches Naturhistorisches Hofmuseum. Vienna.  
 Baden.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Heidelberg.  
 Bavaria.—Königlich Bayerisches Oberbergamt. Munich.  
 California.—State Mining Bureau. San Francisco.  
 Canada.—Geological & Natural History Survey. Ottawa.  
 Finland.—Finlands Geologiska Undersökning. Helsingfors.  
 France.—Dépôt de la Marine. Paris.  
 —. Ministère des Travaux Publics. Paris.  
 —. Muséum d'Histoire Naturelle. Paris.  
 —. Service de la Carte Géologique. Paris.  
 Great Britain.—Army Medical Department. London.  
 —. British Museum (Natural History). London.  
 —. Geological Survey. London.  
 —. Home Office. London.  
 —. Ordnance Survey.  
 —. The Lords Commissioners of Her Majesty's Treasury. London.  
 Hesse.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Darmstadt.  
 Holland.—Departement van Kolonien. The Hague.  
 Hungary.—Königliche Ungarische Geologische Anstalt. Budapest.  
 Illinois.—State Museum of Natural History. Springfield (Ill.).  
 India.—Geological Survey. Calcutta.  
 Italy.—Reale Comitato Geológico d'Italia. Rome.  
 Japan.—Geological Survey. Tokio.  
 La Plata Museum. La Plata.  
 Mexico.—Comision Geológica de Mexico. Mexico.  
 Minnesota.—Geological and Natural History Survey. Minneapolis.  
 Missouri.—Geological Survey of Missouri. Jefferson City (Mo.).  
 New South Wales.—Agent-General for, London.  
 —. Australian Museum. Sydney.  
 —. Department of Lands. Sydney.  
 —. Department of Mines. Sydney.  
 —. Geological Survey. Sydney.  
 New York State Library. Albany.  
 New York State Museum. Albany.  
 Norway.—Norges Geologiska Undersökning. Christiania.  
 Nova Scotia.—Department of Mines. Halifax (N. S.).  
 Perak Government. Taiping.  
 Portugal.—Comissão Geologica de Portugal. Lisbon.  
 Prussia.—Königliche Preussische Geologische Landesanstalt. Berlin.  
 —. Königliches Ministerium für Handel und Gewerbe. Berlin.  
 Queensland.—Geological Survey. Brisbane.  
 Russia.—Comité Géologique. St. Petersburg.  
 Saxony.—Geologische Landesuntersuchung des Königreichs Sachsen. Leipzig.  
 —. Königliches Finanz-Ministerium. Leipzig.  
 South Australia.—The Agent-General for, London.  
 Spain.—Comision del Mapa Geológico. Madrid.  
 Sweden.—Sveriges Geologiska Undersökning. Stockholm.  
 Switzerland.—Commission der Geologischen Karte. Berne.  
 United States Bureau of Ethnology. Washington.  
 United States Department of the Interior. Washington.  
 United States 'Field' Columbian Museum. Chicago.  
 United States Geological Survey. Washington.  
 United States National Museum. Washington.

United States Treasury (Mint) Department. Washington.  
 Victoria.—Department of Mines. Melbourne.  
 Washington (D. C.).—Smithsonian Institution.  
 Western Australia.—Department of Mines. Perth.  
 —. Geological Survey. Perth.  
 —. The Agent-General for, London.

## II. SOCIETIES AND EDITORS.

Adelaide.—Royal Society of South Australia.  
 Alnwick.—Berwickshire Naturalists' Club.  
 Bahia.—Instituto Geographico e Historico.  
 Barnsley (Newcastle-upon-Tyne).—Midland Institute of Mining, Civil and Mechanical Engineers.  
 Basel.—Schweizerische Naturforschende Gesellschaft.  
 Bath Natural History and Antiquarian Field Club.  
 Belfast Natural History and Philosophical Society.  
 Belgrade.—Annales Géologiques de la Péninsule Balkanique.  
 Berkeley (Cal.).—Department of Geology, University of California.  
 Berlin.—Deutsche Geologische Gesellschaft.  
 —. Gesellschaft Naturforschender Freunde.  
 —. Königliche Preussische Akademie der Wissenschaften.  
 —. Zeitschrift für praktische Geologie.  
 Berne.—Allgemeine Schweizerische Gesellschaft für die gesammten Naturwissenschaften.  
 —. Naturforschende Gesellschaft.  
 Birmingham.—Mason College.  
 —. Philosophical Society.  
 Bombay.—Poona College of Science.  
 Boston (Mass.).—American Academy of Arts and Sciences.  
 Boston Society of Natural History.  
 Brussels.—Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique.  
 —. Société Belge de Géologie, de Paléontologie et d'Hydrologie.  
 —. Société Malacologique de Belgique.  
 Budapest.—Földtani Közlöny (Geological Magazine).  
 —. Magyar Földtani Tarsulat.  
 Buenos Aires.—Instituto Geografico Argentino.  
 —. Sociedad Científica Argentina.  
 Caen.—Société Linnéenne de Normandie.  
 Calcutta.—Indian Engineering.  
 —. Asiatic Society of Bengal.  
 Cambridge.—University Library Syndicate.  
 Cambridge (Mass.).—Museum of Comparative Zoology, at Harvard College.  
 Cape Town.—South African Philosophical Society.  
 Cardiff.—South Wales Institute of Engineers.  
 Chicago.—Journal of Geology.  
 Christiania.—Videnskabernes Selskab.  
 Cincinnati Society of Natural History.  
 Colombo.—Ceylon Branch of the Royal Asiatic Society.  
 Colorado Springs (Col.).—Colorado College Scientific Society.  
 Copenhagen.—Dansk Geologisk Forening.  
 —. Kongelige Danske Videnskabernes Selskab.  
 Córdoba (Argentine Republic).—Academia Nacional de Ciencias.  
 Cork.—Queen's College.  
 Cracow.—Académie des Sciences.  
 —. Akademja Umiejetosci.  
 Darmstadt.—Verein für Erdkunde.  
 Dijon.—Académie des Sciences, Arts et Belles-Lettres.  
 Dorchester.—Dorset Natural History and Antiquarian Field Club.  
 Dorpat.—Naturforscher Gesellschaft bei der Universität Jurjew.  
 Douglas.—Isle of Man Natural History and Antiquarian Society.  
 Dresden.—Naturwissenschaftliche Gesellschaft 'Isis.'  
 Dublin.—Royal Irish Academy.  
 Edinburgh.—Royal Scottish Geographical Society.  
 —. Royal Society.

- Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.  
 Falmouth.—Royal Cornwall Polytechnic Society.  
 Frankfurt a. M.—Senckenbergische Naturforschende Gesellschaft.  
 Glasgow.—'Mitchell' Library.  
 Giessen.—Oberhessische Gesellschaft für Natur- und Heilkunde.  
 Glasgow.—Philosophical Society.  
 Gloucester.—Cotteswold Naturalists' Field-Club.  
 Gratz.—Naturwissenschaftlicher Verein für Steiermark.  
 Haarlem.—Société Hollandaise des Sciences.  
 Halifax.—Yorkshire Geological and Polytechnic Society.  
 Halifax (N. S.)—Nova Scotian Institute of Science.  
 Halle.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.  
 Hamilton (Canada).—Hamilton Association.  
 Hanau.—Wetterauische Gesellschaft für die gesammte Naturkunde.  
 Havre.—Société Géologique de Normandie.  
 Hertford.—Hertfordshire Natural History Society.  
 Houghton (Mich.).—Michigan Mining School.  
 Hull.—Geological Society.  
 Ithaca (N. Y.).—Cornell University.  
 Kiev.—Société des Naturalistes.  
 Kingston (Canada).—Queen's College.  
 Lausanne.—Société Géologique Suisse.  
 —. Société Vaudoise des Sciences Naturelles.  
 Leeds.—Geological Association.  
 —. Philosophical Society.  
 Leicester Literary and Philosophical Society.  
 Leipzig.—Naturwissenschaftlicher Verein für Sachsen und Thüringen.  
 —. Zeitschrift für Krystallographie und Mineralogie.  
 —. Zeitschrift für Naturwissenschaften.  
 Liège.—Société Géologique de Belgique.  
 —. Société Royale des Sciences.  
 Lille.—Société Géologique du Nord.  
 Lisbon.—Academia Real das Sciencias.  
 —. Sociedade de Geographia.  
 Liverpool.—Geological Association.  
 —. Geological Society.  
 —. Naturalists' Field-Club.  
 London.—Academy.  
 —. Athenæum.  
 —. British Association for the Advancement of Science.  
 —. Chemical News.  
 —. Chemical Society.  
 —. City of London College.  
 —. Colliery Guardian.  
 —. East India Association.  
 —. Geological Magazine.  
 —. Geologists' Association.  
 —. Institution of Civil Engineers.  
 —. India Rubber, Gutta Percha, and Telegraph Works Co., Lim.  
 —. Iron and Steel Institute.  
 —. Iron and Steel Trades' Journal.  
 —. Knowledge.  
 —. Linnean Society.  
 —. London, Edinburgh, and Dublin Philosophical Magazine.  
 —. Mineralogical Society.  
 —. Nature.  
 —. Palæontographical Society.  
 —. Physical Society.  
 —. Royal Agricultural Society.  
 —. Royal Astronomical Society.  
 —. Royal College of Surgeons.  
 —. Royal Geographical Society.  
 —. Royal Institution.  
 —. Royal Meteorological Society.  
 —. Royal Microscopical Society.  
 —. Royal Photographic Society of Great Britain.  
 —. Royal Society.



- London.—Sanitary Institute.  
 —. Society of Arts.  
 —. Society of Biblical Archaeology.  
 —. Society of Public Analysts.  
 —. University College.  
 —. Victoria Institute.  
 —. Zoological Society.
- Madison (Wis.).—University of Wisconsin.
- Madrid.—Real Academia de Ciencias Exactes, Físicas y Naturales.
- Manchester Geological Society.  
 —. Literary and Philosophical Society.
- Melbourne.—Royal Society of Victoria.
- Mexico.—Sociedad Mexicana de Historia Natural.
- Milan.—Giornale di Mineralogia.  
 —. Reale Istituto Lombardo di Scienze e Lettere.  
 —. Società Italiana di Scienze Naturali.
- Minneapolis.—Minnesota Academy of Natural Sciences.
- Montreal.—Natural History Society.
- Moscow.—Société Impériale des Naturalistes.
- Munich.—Königliche Bayerische Akademie der Wissenschaften.
- Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.
- New Haven (Conn.).—American Journal of Science.  
 —. Connecticut Academy of Arts and Sciences.
- New York.—Academy of Sciences.  
 —. American Institute of Mining Engineers.
- Northampton.—Northamptonshire Natural History Society.
- Oporto.—Sociedade Carlos Ribeiro.
- Ottawa.—Royal Society of Canada.
- Padua.—Reale Accademia di Scienze, Lettere ed Arti.
- Palermo.—Annales de Géologie et de Paléontologie.  
 —. Reale Accademia di Scienze, Lettere ed Arti.
- Paris.—Académie des Sciences.  
 —. Annuaire Géologique Universel.  
 —. Revue Scientifique.  
 —. Société Française de Minéralogie.  
 —. Société Géologique de France.
- Penzance.—Royal Geological Society of Cornwall.
- Philadelphia.—Academy of Natural Sciences.  
 —. American Philosophical Society.  
 —. Wagner Free Institute of Science.
- Pisa.—Reale Università.  
 —. Società Toscana di Scienze Naturali.
- Plymouth.—Devonshire Association for the Advancement of Science.  
 —. Institution, and Devon and Cornwall Natural History Society.
- Port-of-Spain.—Victoria Institute of Trinidad.
- Rochester (N. Y.).—Geological Society of America.
- Rome.—Reale Accademia dei Lincei.  
 —. Società Geologica Italiana.
- Rugby School Natural History Society.
- St. John (N. B.).—Natural History Society.
- St. Petersburg.—Académie Impériale des Sciences.  
 —. Russische Kaiserliche Mineralogische Gesellschaft.
- Santiago.—Deutscher Wissenschaftlicher Verein.  
 —. Sociedad Nacional de Minería.  
 —. Société Scientifique du Chili.
- Scranton (Pa.).—Colliery Engineer.
- Stockholm.—Geologiska Förening.  
 —. Kongliga Svenska Vetenskaps Akademi.
- Stuttgart.—Neues Jahrbuch für Mineralogie, Geologie und Paläontologie.  
 —. Verein für Vaterländische Naturkunde in Württemberg.
- Sydney.—Linnean Society of New South Wales.  
 —. Royal Society of New South Wales.
- Tokyo.—College of Science, Imperial University.  
 —. Imperial University.  
 —. Seismological Journal of Japan.
- Toulouse.—Société d'Histoire Naturelle.
- Truro.—Royal Institution of Cornwall.

Tufts College, Massachusetts.  
 Turin.—Reale Accademia delle Scienze.  
 Upsala Universitet.  
 — Universitets Mineralogisk-Geologiska Institution.  
 Vienna.—Berg- und Hüttenmännisches Jahrbuch.  
 —. Kaiserliche Akademie der Wissenschaften.  
 —. Kaiserlich-königliche Zoologisch-botanische Gesellschaft.  
 —. Mineralogische und Petrographische Mittheilungen.  
 Wellington (N.Z.).—New Zealand Institute.  
 Wiesbaden.—Nassauischer Verein für Naturkunde.  
 York.—Natural History Journal.  
 —. Yorkshire Philosophical Society.

### III. PERSONAL DONORS.

Agassiz, A.  
 Allman, G. J.  
 Ameghino, F.  
 Ami, H. M.

Barlow, W.  
 Barrois, C.  
 Bascom, F.  
 Bauerman, H.  
 Bayley, W. S.  
 Beecher, C. E.  
 Bell, D.  
 Bennett, J. F.  
 Bittner, A.  
 Blake, W. P.  
 Bolton, H.  
 Bonney, T. G.  
 Botte, U.  
 Brodie, P. B.  
 Brögger, W. C.  
 Brongniart, C.  
 Brown, J. A.  
 Brown, N.  
 Brown, H. Y. L.  
 Bukowski, G. von.

Carey, L.  
 Cayeux, L.  
 Chalmers, J. A.  
 Chamberlin, T. C.  
 Claypole, E. W.  
 Cole, E. M.  
 Collins, J. H.  
 Cooke, S.  
 Cope, E. D.  
 Conwentz, H.  
 Crane, A.  
 Crawford, J. J.  
 Credner, H.

Dames, W.  
 Davies, T. W.  
 Dawson, Sir J. J. William.  
 Delebecque, A.  
 Destinez, P.  
 Dollfus, G. F.  
 Doyle, P.  
 Draper, D.  
 Dubois, E.  
 Duparc, L.

Egger, J. G.  
 Exton, H.  
 Faggiotto, A.  
 Fairchild, H. L.  
 Fayol, H.  
 Felix, J.  
 Fisher, O.  
 Floyer, E. A.  
 Fornasini, C.  
 Foster, C. Le Neve.  
 Fouqué, F.  
 Fowler, T. W.  
 Fox, Howard.  
 Fritsch, A.

Gagel, C.  
 Geikie, Sir A.  
 Geikie, J.  
 Gilbert, G. K.  
 Gilpin, E., Jun.  
 Gosselet, J.  
 Gregorio, Marquis  
 Antonio de.  
 Gresley, W. S.

Hall, Marshall.  
 Hanks, H. G.  
 Hargreaves, T. S.  
 Harker, A.  
 Harle, E.  
 Harrison, W. J.  
 Hatch, F. H.  
 Heim, A.  
 Heimbach, H.  
 Hennig, A.  
 Hill, H.  
 Hill, R. T.  
 Hills, R. C.  
 Hinde, G. J.  
 Hobbs, W. H.  
 Holzapfel, E.  
 Hopkinson, J.  
 Hoskold, H. D.  
 Hoyle, W. E.  
 Hull, E.  
 Hume, W. F.

Jack, R. L.  
 James, J. F.

Johnston-Lavis, H. J.  
 Jones, T. R.  
 Jordan, H. K.

Karrer, F.  
 Kayser, E.  
 Kendall, P. F.  
 Keyes, C. R.  
 Kirkby, J. W.  
 Klement, C.  
 Koenen, A. von.  
 Kossmat, F.  
 Kuntze, O.  
 Kurtz, F.

Leighton, T.  
 Liversidge, A.  
 Loeffelholz von Colberg,  
 C.  
 Lorient, P. de.  
 Lyell, Mrs. Katherine.  
 Lyman, B. S.

McHenry, A.  
 Mackinnon, A. K.  
 Mallet, F. R.  
 Mansel-Pleydell, J. C.  
 Manson, M.  
 Marsh, O. C.  
 Matthews, W.  
 Meli, R.  
 Merrill, G. P.  
 Mill, H. R.  
 Milne, J.  
 Monckton, H. W.  
 Moody, T. P.  
 Morton, G. H.  
 Mrazec, L.

Nathorst, A. G.  
 Newton, E. T.  
 Newton, R. B.  
 Nicholas, W.  
 Nordenskjöld, O. G.

Platt, S. S.  
 Pompeckj, J. F.  
 Power, F. D.  
 Preller, C. S. Du Riche.  
 Prestwich, Sir J.

Ramsay, A.  
Ransome, F. L.  
Reade, T. Mellard.  
Reid, C.  
Reyer, E.  
Renevier, E.  
Reusch, Hans.  
Richards, Sir G. H.  
Richardson, R.  
Ritter, E.  
Rosenbusch, H.  
  
Sandberger, F. von.  
Sauvage, H. E.  
Scudder, S. H.  
Seeley, H. G.  
Shillingford, F. A.  
Sherborn, C. D.  
Shipman, J.  
Sjögren, H.  
Smith, E. A.

Spencer, J. W.  
Spezia, G.  
Stanley, W. F.  
Stefanescu, G.  
Stevenson, W.  
Storrie, J.  
Story-Maskelyne, N.  
Strahan, A.  
Suess, E.  
  
Tate, T.  
Thugutt, S. J.  
Trabucco, G.  
Tschermak, G.  
  
Upham, W.  
  
Vaughan, T. W.  
  
Wähner, F.  
Walford, E. A.

Wardell, F. N.  
Walther, J.  
Watts, W. W.  
Wehrli, L.  
Whidborne, G. F.  
Whitaker, W.  
Wilson, E.  
Wiman, C.  
Winchell, N. H.  
Winslow, A.  
Winwood, H. H.  
Woodward, A. S.  
Woodward, H.  
Woodward, H. B.  
Woodward, H. P.  
Wray, L., Jun.  
  
Zeiller, R.  
Zujović, J. M.

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COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE  
CLOSE OF THE YEARS 1894 AND 1895.

	Dec. 31st, 1894.	Dec. 31st, 1895.
Compounders .....	305	305
Contributing Fellows.....	862	867
Non-contributing Fellows ..	75	69
	<hr/>	<hr/>
	1242	1241
Foreign Members .....	40	39
Foreign Correspondents....	39	38
	<hr/>	<hr/>
	1321	1318

*Comparative Statement explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1894 and 1895.*

Number of Compounders, Contributing and Non-contributing Fellows, December 31st, 1894 ..	}	1242
Add Fellows elected during former year and paid in 1895 .....		12
Add Fellows elected and paid in 1895 .....		32
		<hr/>
		1286
Deduct Compounders deceased .....		9
Contributing Fellows deceased .....		10
Non-contributing Fellows deceased .....		6
Contributing Fellows resigned .....		10
Contributing Fellows removed .....		10
		<hr/>
		45
		<hr/>
		1241
Number of Foreign Members and Foreign Correspondents, December 31st, 1894 ....	}	79
Deduct Foreign Members deceased .....		4
Foreign Correspondent deceased ....	1	
Foreign Correspondents elected }	}	3
Foreign Members .....		
		<hr/>
		8
		<hr/>
		71
Add Foreign Members elected .....		3
Foreign Correspondents elected .....		3
		<hr/>
		77
		<hr/>
		1318

## DECEASED FELLOWS.

*Compounders (9).*

Ball, V., Esq.	Lawrence, P. H., Esq.
Browne, Ven. Archdeacon.	Mitchell, J., Esq.
Carter, R., Esq.	Slatter, T. J., Esq.
Cline, Dr. G. W.	Tyler, C., Esq.
Johnson, F., Esq.	

*Resident and other Contributing Fellows (10).*

Bunbury, Sir E. H.	Hulke, J. W., Esq.
Carter, J., Esq.	Huxley, Rt. Hon. T. H.
Chance, E. J., Esq.	Milnes, W. S., Esq.
Copland-Crawford, Lt.-Gen. R.F.	Williams, J. E., Esq.
Hosking, G. F., Esq.	Wünsch, E. A., Esq.

*Non-contributing Fellows (6).*

Babington, Prof. C. C.	Lester, Rev. Lester.
Duke, Rev. E.	Mantell, W. B. D., Esq.
Fitch, R., Esq.	Tayler, J. W., Esq.

*Foreign Members (4).*

Dana, Prof. J. D.	Rütimeyer, Prof. L.
Lovén, Prof. Sven.	Saporta, Marquis G. de.

*Foreign Correspondent (1).*

Castillo, Don Antonio del.

## FELLOWS RESIGNED (10).

Baldwin, A. E., Esq.	Routh, C. S., Esq.
Isaac, T. W. P., Esq.	Sherwood, W., Esq.
Johnson, M. H., Esq.	Whitmell, C. T., Esq.
King, Dr. W.	Willelt, H., Esq.
Plowright, H. J., Esq.	Winter, T., Esq.

## FELLOWS REMOVED (10).

Ballard, Rev. F.	Milles, R. S., Esq.
Browne, C., Esq.	Muir, E., Esq.
Burns, D., Esq.	Ratnavelacharia, M., Esq.
Gilpin, E., Esq.	Rowlandson, T., Esq.
Maude, Captain F. N.	Wilson-Moore, C., Esq.

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*The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1895:—*

Monsieur F. Schmidt, of St. Petersburg.  
 Professor W. Dames, of Berlin.  
 Professor G. K. Gilbert, of Washington, U.S.A.

*The following Personages were elected Foreign Correspondents during the year 1895:—*

Dr. K. de Kroustchoff, of St. Petersburg.  
 Professor Paul Groth, of Munich.  
 Professor A. Penck, of Vienna.

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After the Reports had been read, it was resolved :—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved :—

That the thanks of the Society be given to Dr. Henry Woodward, retiring from the office of President.

That the thanks of the Society be given to W. H. Hudleston, Esq., retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. G. J. Hinde, W. H. Hudleston, Esq., Prof. J. W. Judd, the Rev. H. H. Winwood, and H. B. Woodward, Esq., retiring from the Council.

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After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

## OFFICERS AND COUNCIL.—1896.

*PRESIDENT.*

Henry Hicks, M.D., F.R.S.

*VICE-PRESIDENTS.*

Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.

Prof. A. H. Green, M.A., F.R.S.

R. Lydekker, Esq., B.A., F.R.S.

Lieut.-General C. A. McMahon.

*SECRETARIES.*

J. E. Marr, Esq., M.A., F.R.S.

J. J. H. Teall, Esq., M.A., F.R.S.

*FOREIGN SECRETARY.*

Sir John Evans, K.C.B., LL.D., F.R.S., F.L.S.

*TREASURER.*

W. T. Blanford, LL.D., F.R.S.

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COUNCIL.

H. Bauerman, Esq.

W. T. Blanford, LL.D., F.R.S.

Prof. T. G. Bonney, D.Sc., LL.D.,  
F.R.S.

Horace T. Brown, Esq., F.R.S.

Prof. W. Boyd Dawkins, M.A., F.R.S.

Sir John Evans, K.C.B., LL.D.,  
F.R.S., F.L.S.Sir Archibald Geikie, D.Sc., LL.D.,  
F.R.S.

Prof. A. H. Green, M.A., F.R.S.

J. W. Gregory, D.Sc.

F. W. Harmer, Esq.

R. S. Herries, Esq., M.A.

Henry Hicks, M.D., F.R.S.

Rev. E. Hill, M.A.

T. V. Holmes, Esq.

R. Lydekker, Esq., B.A., F.R.S.

Lieut.-General C. A. McMahon.

J. E. Marr, Esq., M.A., F.R.S.

Prof. Henry A. Miers, M.A.

E. T. Newton, Esq., F.R.S.

F. Rutley, Esq.

A. Strahan, Esq., M.A.

J. J. H. Teall, Esq., M.A., F.R.S.

Henry Woodward, LL.D., F.R.S.

*ASSISTANT-SECRETARY, CLERK, LIBRARIAN, AND CURATOR.*

L. L. Belinfante, B.Sc.

*ASSISTANTS IN OFFICE, LIBRARY, AND MUSEUM.*

W. Rupert Jones.

Clyde H. Black.



# LIST OF THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1895.

Date of Election.	
1848.	James Hall, Esq., <i>Albany, State of New York, U.S.A.</i>
1851.	Professor James D. Dana, <i>New Haven, Conn., U.S.A. (Deceased.)</i>
1856.	Professor Robert Bunsen, For. Mem. R.S., <i>Heidelberg.</i>
1857.	Professor H. B. Geinitz, <i>Dresden.</i>
1867.	Professor A. Daubrée, For. Mem. R.S., <i>Paris.</i>
1871.	Dr. Franz Ritter von Hauer, <i>Vienna.</i>
1874.	Professor Albert Gaudry, <i>Paris.</i>
1875.	Professor Fridolin Sandberger, <i>Würzburg.</i>
1876.	Professor E. Beyrich, <i>Berlin.</i>
1877.	Dr. Carl Wilhelm Gümbel, <i>Munich.</i>
1877.	Dr. Eduard Suess, <i>Vienna.</i>
1879.	M. Jules Marcou, <i>Cambridge, Mass., U.S.A.</i>
1879.	Dr. J. J. S. Steenstrup, For. Mem. R.S., <i>Copenhagen.</i>
1880.	Professor Gustave Dewalque, <i>Liège.</i>
1880.	Baron Adolf Erik Nordenskiöld, <i>Stockholm.</i>
1880.	Professor Ferdinand Zirkel, <i>Leipzig.</i>
1882.	Professor Sven Lovén, <i>Stockholm. (Deceased.)</i>
1882.	Professor Ludwig Rüttimeyer, <i>Basel. (Deceased.)</i>
1883.	Professor Otto Martin Torell, <i>Stockholm.</i>
1884.	Professor G. Capellini, <i>Bologna.</i>
1884.	Professor A. L. O. Des Cloizeaux, For. Mem. R.S., <i>Paris.</i>
1885.	Professor Jules Gosselet, <i>Lille.</i>
1886.	Professor Gustav Tschermak, <i>Vienna.</i>
1887.	Professor J. P. Lesley, <i>Philadelphia, Pa., U.S.A.</i>
1887.	Professor J. D. Whitney, <i>Cambridge, Mass., U.S.A.</i>
1888.	Professor Eugène Renevier, <i>Lausanne.</i>
1888.	Baron Ferdinand von Richthofen, <i>Berlin.</i>
1889.	Professor Ferdinand Fouqué, <i>Paris.</i>
1889.	Marquis Gaston de Saporta, <i>Aix-en-Provence. (Deceased.)</i>
1889.	Geheimrath Professor Karl Alfred von Zittel, <i>Munich.</i>
1890.	Professor Heinrich Rosenbusch, <i>Heidelberg.</i>
1891.	Dr. Charles Barrois, <i>Lille.</i>
1892.	Professor Gustav Lindström, <i>Stockholm.</i>
1893.	Professor Waldemar Christofer Brögger, <i>Christiania.</i>
1893.	M. Auguste Michel-Lévy, <i>Paris.</i>
1893.	Dr. Edmund Mojsisovics von Mojsvár, <i>Vienna.</i>
1893.	Dr. Alfred Gabriel Nathorst, <i>Stockholm.</i>
1894.	Professor George J. Brush, <i>New Haven, Conn., U.S.A.</i>
1894.	Professor Edward Salisbury Dana, <i>New Haven, Conn., U.S.A.</i>
1894.	Professor Alphonse Renard, <i>Ghent.</i>
1895.	Professor Wilhelm Dames, <i>Berlin.</i>
1895.	Professor Grove K. Gilbert, <i>Washington, U.S.A.</i>
1895.	M. Friedrich Schmidt, <i>St. Petersburg.</i>

# LIST OF THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1895.

Date of Election.	
1866.	Professor Victor Raulin, <i>Montfaucon d'Argonne</i> .
1874.	Professor Iginò Cocchi, <i>Florence</i> .
1874.	Dr. T. C. Winkler, <i>Haarlem</i> .
1879.	M. Édouard Dupont, <i>Brussels</i> .
1879.	Dr. Émile Sauvage, <i>Boulogne-sur-Mer</i> .
1881.	Professor E. D. Cope, <i>Philadelphia, Pa., U.S.A.</i>
1882.	Professor Louis Lartet, <i>Toulouse</i> .
1882.	Professor Alphonse Milne-Edwards, <i>Paris</i> .
1884.	M. Alphonse Briart, <i>Morlanwelz</i> .
1884.	Professor Hermann Credner, <i>Leipzig</i> .
1884.	Baron C. von Ettingshausen, <i>Grätz</i> .
1887.	Senhor J. F. N. Delgado, <i>Lisbon</i> .
1887.	Professor A. Heim, <i>Zürich</i> .
1887.	Professor A. de Lapparent, <i>Paris</i> .
1888.	M. Charles Brongniart, <i>Paris</i> .
1888.	Professor Anton Fritsch, <i>Prague</i> .
1888.	M. Ernest Van den Broeck, <i>Brussels</i> .
1889.	Dr. Hans Reusch, <i>Christiania</i> .
1889.	M. R. D. M. Verbeek, <i>Padang, Sumatra</i> .
1890.	M. Gustave F. Dollfus, <i>Paris</i> .
1890.	Herr Felix Karrer, <i>Vienna</i> .
1890.	Professor Adolph von Könen, <i>Göttingen</i> .
1891.	Señor Don Antonio del Castillo, <i>Mexico</i> . (Deceased.)
1891.	Professor Emanuel Kayser, <i>Marburg</i> .
1892.	Professor Johann Lehmann, <i>Kiel</i> .
1892.	Major John W. Powell, <i>Washington, D.C., U.S.A.</i>
1893.	Professor Marcel Bertrand, <i>Paris</i> .
1893.	Professor Aléxis Pavlow, <i>Moscow</i> .
1893.	M. Ed. Rigaux, <i>Boulogne-sur-Mer</i> .
1893.	Dr. Sven Leonhard Törnquist, <i>Lund</i> .
1893.	Dr. Charles Abiathar White, <i>Washington, D.C., U.S.A.</i>
1894.	Professor Joseph Paxson Iddings, <i>Chicago, Ill., U.S.A.</i>
1894.	M. Perceval de Loriol-Lefort, <i>Campagne Frontenex</i> .
1894.	Dr. Francisco P. Moreno, <i>La Plata</i> .
1894.	Dr. A. Rothpletz, <i>Munich</i> .
1894.	Professor J. H. L. Vogt, <i>Christiania</i> .
1895.	Professor Paul Groth, <i>Munich</i> .
1895.	Dr. K. de Kroustchoff, <i>St. Petersburg</i> .
1895.	Professor Albrecht Penck, <i>Vienna</i> .

# AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

'To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,'—'such individual not being a Member of the Council.'

- |                                     |                                   |
|-------------------------------------|-----------------------------------|
| 1831. Mr. William Smith.            | 1865. Dr. Thomas Davidson.        |
| 1835. Dr. G. A. Mantell.            | 1866. Sir Charles Lyell.          |
| 1836. M. Louis Agassiz.             | 1867. Mr. G. Poulett Scrope.      |
| 1837. } Capt. T. P. Cautley.        | 1868. Professor Carl F. Naumann.  |
| } Dr. H. Falconer.                  | 1869. Dr. H. C. Sorby.            |
| 1838. Sir Richard Owen.             | 1870. Professor G. P. Deshayes.   |
| 1839. Professor C. G. Ehrenberg.    | 1871. Sir A. C. Ramsay.           |
| 1840. Professor A. H. Dumont.       | 1872. Professor J. D. Dana.       |
| 1841. M. Adolphe T. Brongniart.     | 1873. Sir P. de M. Grey Egerton.  |
| 1842. Baron L. von Buch.            | 1874. Professor Oswald Heer.      |
| 1843. } M. Élie de Beaumont.        | 1875. Professor L. G. de Koninck. |
| } M. P. A. Dufrénoy.                | 1876. Professor T. H. Huxley.     |
| 1844. Rev. W. D. Conybeare.         | 1877. Mr. Robert Mallet.          |
| 1845. Professor John Phillips.      | 1878. Dr. Thomas Wright.          |
| 1846. Mr. William Lonsdale.         | 1879. Professor Bernhard Studer.  |
| 1847. Dr. Ami Boué.                 | 1880. Professor Auguste Daubrée.  |
| 1848. Rev. Dr. W. Buckland.         | 1881. Professor P. Martin Duncan. |
| 1849. Professor Joseph Prestwich.   | 1882. Dr. Franz Ritter von Hauer. |
| 1850. Mr. William Hopkins.          | 1883. Dr. W. T. Blanford.         |
| 1851. Rev. Prof. A. Sedgwick.       | 1884. Professor Albert Gaudry.    |
| 1852. Dr. W. H. Fitton.             | 1885. Mr. George Busk.            |
| 1853. } M. le Vicomte A. d'Archiac. | 1886. Professor A. L. O. Des      |
| } M. E. de Verneuil.                | Cloiseaux.                        |
| 1854. Sir Richard Griffith.         | 1887. Mr. J. Whitaker Hulke.      |
| 1855. Sir H. T. De la Beche.        | 1888. Mr. H. B. Medlicott.        |
| 1856. Sir W. E. Logan.              | 1889. Professor T. G. Bonney.     |
| 1857. M. Joachim Barrande.          | 1890. Professor W. C. Williamson. |
| 1858. } Herr Hermann von Meyer.     | 1891. Professor J. W. Judd.       |
| } Mr. James Hall.                   | 1892. Baron Ferdinand von         |
| 1859. Mr. Charles Darwin.           | Richthofen.                       |
| 1860. Mr. Searles V. Wood.          | 1893. Professor N. S. Maskelyne.  |
| 1861. Professor Dr. H. G. Bronn.    | 1894. Geheimrath Professor Karl   |
| 1862. Mr. R. A. C. Godwin-Austen.   | Alfred von Zittel.                |
| 1863. Professor Gustav Bischof.     | 1895. Sir Archibald Geikie.       |
| 1864. Sir R. I. Murchison.          | 1896. Dr. Eduard Suess.           |

## A W A R D S

## OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON  
'DONATION FUND.'

- |                                    |                                    |
|------------------------------------|------------------------------------|
| 1831. Mr. William Smith.           | 1865. Mr. J. W. Salter.            |
| 1833. Mr. William Lonsdale.        | 1866. Dr. Henry Woodward.          |
| 1834. M. Louis Agassiz.            | 1867. Mr. W. H. Baily.             |
| 1835. Dr. G. A. Mantell.           | 1868. M. J. Bosquet.               |
| 1836. Professor G. P. Deshayes.    | 1869. Mr. W. Carruthers.           |
| 1838. Sir Richard Owen.            | 1870. M. Marie Rouault.            |
| 1839. Professor C. G. Ehrenberg.   | 1871. Mr. R. Etheridge.            |
| 1840. Mr. J. De Carle Sowerby.     | 1872. Dr. James Croll.             |
| 1841. Professor Edward Forbes.     | 1873. Professor J. W. Judd.        |
| 1842. Professor John Morris.       | 1874. Dr. Henri Nyst.              |
| 1843. Professor John Morris.       | 1875. Mr. L. C. Miall.             |
| 1844. Mr. William Lonsdale.        | 1876. Professor Giuseppe Seguenza. |
| 1845. Mr. Geddes Bain.             | 1877. Mr. R. Etheridge, Jun.       |
| 1846. Mr. William Lonsdale.        | 1878. Professor W. J. Sollas.      |
| 1847. M. Alcide d'Orbigny.         | 1879. Mr. Samuel Allport.          |
| 1848. { Cape-of-Good-Hope Fossils. | 1880. Mr. Thomas Davies.           |
| { M. Alcide d'Orbigny.             | 1881. Dr. R. H. Traquair.          |
| 1849. Mr. William Lonsdale.        | 1882. Dr. G. J. Hinde.             |
| 1850. Professor John Morris.       | 1883. Professor John Milne.        |
| 1851. M. Joachim Barrande.         | 1884. Mr. E. Tulley Newton.        |
| 1852. Professor John Morris.       | 1885. Dr. Charles Callaway.        |
| 1853. Professor L. G. de Koninck.  | 1886. Mr. J. S. Gardner.           |
| 1854. Dr. S. P. Woodward.          | 1887. Mr. B. N. Peach.             |
| 1855. Drs. G. and F. Sandberger.   | 1888. Mr. J. Horne.                |
| 1856. Professor G. P. Deshayes.    | 1889. Mr. A. Smith Woodward.       |
| 1857. Dr. S. P. Woodward.          | 1890. Mr. W. A. E. Ussher.         |
| 1858. Mr. James Hall.              | 1891. Mr. R. Lydekker.             |
| 1859. Mr. Charles Peach.           | 1892. Mr. O. A. Derby.             |
| 1860. { Professor T. Rupert Jones. | 1893. Mr. J. G. Goodchild.         |
| { Mr. W. K. Parker.                | 1894. Mr. Aubrey Strahan.          |
| 1861. Professor A. Daubrée.        | 1895. Mr. W. W. Watts.             |
| 1862. Professor Oswald Heer.       | 1896. Mr. Alfred Harker.           |
| 1863. Professor Ferdinand Senft.   |                                    |
| 1864. Professor G. P. Deshayes.    |                                    |
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## AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

'To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

- |  |  |
|--|--|
| 1873. Mr. William Davies. <i>Medal.</i>    | 1886. Mr. W. Whitaker. <i>Medal.</i>   |
| 1873. Professor Oswald Heer.               | 1886. Mr. Clement Reid.                |
| 1874. Dr. J. J. Bigsby. <i>Medal.</i>      | 1887. Rev. P. B. Brodie. <i>Medal.</i> |
| 1874. Mr. Alfred Bell.                     | 1887. Mr. Robert Kidston.              |
| 1874. Professor Ralph Tate.                | 1888. Professor J. S. Newberry.        |
| 1875. Mr. W. J. Henwood. <i>Medal.</i>     | <i>Medal.</i>                          |
| 1875. Professor H. G. Seeley.              | 1888. Mr. Edward Wilson.               |
| 1876. Mr. A. R. C. Selwyn.                 | 1889. Professor James Geikie.          |
| <i>Medal.</i>                              | <i>Medal.</i>                          |
| 1876. Dr. James Croll.                     | 1889. Professor G. A. J. Cole.         |
| 1877. Rev. W. B. Clarke. <i>Medal.</i>     | 1890. Professor Edward Hull.           |
| 1877. Rev. J. F. Blake.                    | <i>Medal.</i>                          |
| 1878. Dr. H. B. Geinitz. <i>Medal.</i>     | 1890. Mr. E. Wethered.                 |
| 1878. Professor Charles Lapworth.          | 1891. Professor W. C. Brögger.         |
| 1879. Professor F. M'Coy. <i>Medal.</i>    | <i>Medal.</i>                          |
| 1879. Mr. J. W. Kirkby.                    | 1891. Rev. R. Baron.                   |
| 1880. Mr. R. Etheridge. <i>Medal.</i>      | 1892. Professor A. H. Green.           |
| 1881. Sir Archibald Geikie. <i>Medal.</i>  | <i>Medal.</i>                          |
| 1881. Mr. F. Rutley.                       | 1892. Mr. Beeby Thompson.              |
| 1882. Professor J. Gosselet. <i>Medal.</i> | 1893. Rev. O. Fisher. <i>Medal.</i>    |
| 1882. Professor T. Rupert Jones.           | 1893. Mr. G. J. Williams.              |
| 1883. Professor H. R. Göppert.             | 1894. Mr. W. T. Aveline. <i>Medal.</i> |
| <i>Medal.</i>                              | 1894. Mr. George Barrow.               |
| 1883. Mr. John Young.                      | 1895. Professor Gustav Lind-           |
| 1884. Dr. H. Woodward. <i>Medal.</i>       | ström. <i>Medal.</i>                   |
| 1884. Mr. Martin Simpson.                  | 1895. Mr. A. C. Seward.                |
| 1885. Dr. Ferdinand von Römer              | 1896. Mr. T. Mellard Reade.            |
| <i>Medal.</i>                              | <i>Medal.</i>                          |
| 1885. Mr. Horace B. Woodward.              | 1896. Mr. Philip Lake.                 |

## AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE 'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal 'to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

- |   |   |
|---|---|
| 1876. Professor John Morris.<br><i>Medal.</i>   | 1888. Professor H. A. Nicholson.<br><i>Medal.</i>   |
| 1877. Dr. James Hector. <i>Medal.</i>           | 1888. Mr. A. H. Foord.                              |
| 1877. Mr. W. Pengelly.                          | 1888. Mr. Thomas Roberts.                           |
| 1878. Mr. G. Busk. <i>Medal.</i>                | 1889. Professor W. Boyd Dawkins.<br><i>Medal.</i>   |
| 1878. Professor W. Waagen.                      | 1889. M. Louis Dollo.                               |
| 1879. Professor Edmond Hébert.<br><i>Medal.</i> | 1890. Professor T. Rupert Jones.<br><i>Medal.</i>   |
| 1879. Professor H. A. Nicholson.                | 1890. Mr. C. Davies Sherborn.                       |
| 1879. Dr. Henry Woodward.                       | 1891. Professor T. McKenny<br>Hughes. <i>Medal.</i> |
| 1880. Sir John Evans. <i>Medal.</i>             | 1891. Dr. C. J. Forsyth-Major.                      |
| 1880. Professor F. A. von Quen-<br>stedt.       | 1891. Mr. G. W. Lamplugh.                           |
| 1881. Sir J. W. Dawson. <i>Medal.</i>           | 1892. Mr. G. H. Morton. <i>Medal.</i>               |
| 1881. Dr. Anton Fritsch.                        | 1892. Dr. J. W. Gregory.                            |
| 1881. Mr. G. R. Vine.                           | 1892. Mr. E. A. Walford.                            |
| 1882. Dr. J. Lycett. <i>Medal.</i>              | 1893. Mr. E. T. Newton. <i>Medal.</i>               |
| 1882. Rev. Norman Glass.                        | 1893. Miss C. A. Raisin.                            |
| 1882. Professor Charles Lapworth.               | 1893. Mr. A. N. Leeds.                              |
| 1883. Dr. W. B. Carpenter. <i>Medal.</i>        | 1894. Professor John Milne.<br><i>Medal.</i>        |
| 1883. Mr. P. H. Carpenter.                      | 1894. Mr. William Hill.                             |
| 1883. M. E. Rigaux.                             | 1895. Rev. J. F. Blake. <i>Medal.</i>               |
| 1884. Dr. Joseph Leidy. <i>Medal.</i>           | 1895. Mr. Percy F. Kendall.                         |
| 1884. Professor Charles Lapworth.               | 1895. Mr. Benjamin Harrison.                        |
| 1885. Professor H. G. Seeley.<br><i>Medal.</i>  | 1896. Mr. A. Smith Woodward.<br><i>Medal.</i>       |
| 1885. Mr. A. J. Jukes-Browne.                   | 1896. Dr. W. F. Hume.                               |
| 1886. Mr. W. Pengelly. <i>Medal.</i>            | 1896. Mr. C. W. Andrews.                            |
| 1886. Mr. D. Mackintosh.                        |   |
| 1887. Mr. Samuel Allport. <i>Medal.</i>         |   |
| 1887. Rev. Osmond Fisher.                       |   |

## AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Professor O. C. Marsh.	1887. Professor Charles Lapworth.
1879. Professor E. D. Cope.	1889. Mr. J. J. Harris Teall.
1881. Dr. Charles Barrois.	1891. Dr. George M. Dawson.
1883. Dr. Henry Hicks.	1893. Professor W. J. Sollas.
1885. Professor Alphonse Renard.	1895. Mr. Charles D. Walcott.

## AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1880. Purchase of microscope.	1892. Professor Charles Mayer-Eymar.
1881. Purchase of microscope-lamps.	1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1882. Baron C. von Ettingshausen.	1894. Mr. Charles Davison.
1884. Dr. James Croll.	1896. Mr. J. Wright.
1884. Professor Leo Lesquereux.	1896. Mr. J. Storrie.
1886. Dr. H. J. Johnston-Lavis.	
1888. Museum.	
1890. Mr. W. Jerome Harrison.	

ESTIMATES *for*

## INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions.....	136	0	0			
Due for Arrears of Admission Fees .....	69	6	0			
Admission Fees, 1896 .....	180	0	0			
				249	6	0
Arrears of Annual Contributions .....	110	0	0			
Annual Contributions, 1896, from Resident Fellows, and Non-Residents, 1859 to 1861 ....	1630	0	0			
Annual Contributions in advance .....	35	0	0			
				1775	0	0
Dividends on £2000 India 3 per cents. ....	60	0	0			
Dividends on £2250 London and North-Western Railway 4 per cent. Preference Stock .....	90	0	0			
Dividends on £2800 London and South-Western Railway 4 per cent. Preference Stock .....	112	0	0			
Dividends on £300 London, Brighton, and South Coast Railway 5 per cent. Preference Stock..	15	0	0			
Dividends on £1295 Midland Railway 4 per cent. Preference Stock .....	51	16	0			
				328	16	0
Sale of Quarterly Journal, including Longman's Account .....	150	0	0			
Sale of Geological Map, including Stanford's Account .....	10	0	0			
Sale of Transactions, Library Catalogue, Ormerod's Index, Hochstetter's 'New Zealand,' and List of Fellows .....	5	0	0			
				165	0	0
Balance against Society .....	608	6	0			
				£3262	8	0

*Note.*—The following Funds are available for Extraordinary Expenditure.

	£	s.	d.
Balance at the Bankers', Dec. 31st, 1895.....	835	5	10
Balance in the Clerk's hands, Dec. 31st, 1895 .....	16	9	7
	£851	15	5



*the Year 1896.*

## EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
<b>House Expenditure:</b>						
Taxes .....	0	15	0			
Fire Insurance .....	15	0	0			
Gas .....	25	0	0			
Fuel .....	30	0	0			
Furniture and Repairs .....	35	0	0			
House-repairs and Maintenance .....	30	0	0			
Annual Cleaning .....	15	0	0			
Washing and Sundries .....	25	0	0			
Tea at Meetings .....	15	0	0			
				190	15	0
<b>Salaries and Wages, etc.:</b>						
Assistant Secretary .....	300	0	0			
"    Half Premium of Life Insurance .....	10	15	0			
Assistant Librarian .....	150	0	0			
Assistant Clerk .....	80	0	0			
House Porter and Upper-Housemaid .....	91	12	0			
Under-Housemaid .....	42	12	0			
Errand Boy .....	31	4	0			
Charwoman and Occasional Assistance .....	10	0	0			
Accountant's Fee .....	10	10	0			
				726	13	0
<b>Library (Books and Binding) .....</b>				250	0	0
<b>Museum .....</b>				5	0	0
<b>Office Expenditure:</b>						
Stationery .....	25	0	0			
Miscellaneous Printing .....	30	0	0			
Postages and other Expenses .....	80	0	0			
				135	0	0
<b>Publications:</b>						
Geological Map .....	10	0	0			
Quarterly Journal .....	850	0	0			
"    "    Commission, Postage, and Addressing .....	100	0	0			
Record of Geological Literature .....	75	0	0			
List of Fellows .....	35	0	0			
Abstracts, including Postage .....	110	0	0			
				1180	0	0
<b>Index to Quarterly Journal, vols. 1-50 (sanctioned by Special General Meeting, June 21st, 1893) .....</b>				375	0	0
<b>Electric Lighting of Society's Apartments .....</b>				300	0	0
<b>Partial Redecoration of Society's Apartments .....</b>				100	0	0
				<u>£3262</u>	<u>8</u>	<u>0</u>

*Income and Expenditure during the*

## RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January, 1895 .	345	1	8			
Balance in Clerk's hands, 1 January, 1895 .	13	7	5			
				358	9	1
Compositions .....				305	18	0
Arrears of Admission-fees .....	75	12	0			
Admission-fees .....	182	14	0			
				258	6	0
Arrears of Annual Contributions .....				157	12	7
Annual Contributions of 1895 :						
Resident Fellows .....	1624	17	6			
Non-Resident Fellows ...	11	0	6			
				1635	18	0
Annual Contributions in advance .....				39	18	0
Taylor & Francis : Advertisements in Journal, Vol. 50 ..				15	0	
Publications :						
Sale of Journal, Vols. 1-50 .....	85	0	3			
"    Vol. 51 * .....	72	12	8			
Sale of Library Catalogue .....		5	0			
Sale of Geological Map .....	9	3	0			
Sale of Ormerod's Index .....		14	2			
Sale of Hochstetter's 'New Zealand' .....		6	0			
Sale of List of Fellows .....		8	3			
				168	9	4
Dividends on L. & N. W. Railway Stock ..	87	0	0			
"    L. & S. W. Railway Stock ..	108	5	4			
"    L. B. & S. C. Railway Stock ..	14	10	0			
"    Midland Railway Stock ....	25	0	9			
"    2 $\frac{3}{4}$ p. c. Consolidated Stock ..	50	2	0			
"    India 3 p. c. Stock .....	29	0	0			
				313	18	1
Sale of £3769 2s. 6d. 2 $\frac{3}{4}$ p. c. Consolidated Stock at 104 $\frac{3}{8}$ .....				3934	0	6
Income Tax :						
Repayment of Tax under Schedule C for the year 1894-95 .....				10	9	3

\*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 51, £62 8s. 1d.

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

(Signed) B. H. BROUGH, } *Auditors.*  
R. S. HERRIES, }

January 27th, 1896.

£7183 13 10

*Year ended December 31st, 1895.*

PAYMENTS.

House Expenditure:	£	s.	d.	£	s.	d.
Taxes .....	3	15	0			
Fire Insurance .....	15	0	0			
Gas .....	24	9	7			
Fuel.....	26	9	11			
Furniture and Repairs .....	55	4	11			
House Repairs .....	29	7	4			
Annual Cleaning .....	10	15	0			
Washing and Sundries .....	22	13	2			
Tea at Meetings.....	13	12	1			
				201	7	0
Salaries and Wages:						
Assistant Secretary .....	250	0	0			
"    Half Life Insurance premium	10	15	0			
Assistants in Library, Office, and Museum...	251	5	6			
House Porter and Upper-Housemaid (including Uniform and Allowance for Washing) }	91	13	3			
Housemaid (including Allowance for Washing) }	42	13	3			
Errand Boy .....	29	8	0			
Charwoman and Occasional Assistance .....	4	19	0			
Accountant's Fee .....	10	10	0			
				691	4	0
Office Expenditure:						
Stationery .....	25	4	2			
Miscellaneous Printing .....	43	11	1			
Postages and Sundry Expenses .....	89	5	10			
Gratuities to Assistant-Secretary and Assistant-Librarian .....	40	0	0			
				198	1	1
Library .....				171	0	6
Museum .....				50	0	0
Publications:						
Geological Map .....	4	15	7			
Journal, Vols. 1-50.....	7	11	2			
"    Vol. 51 .....	738	14	1			
"    Commission,						
Postage, and Addressing. ....	85	9	0			
				824	3	1
List of Fellows .....	35	18	4			
Abstracts, including Postage .....	107	4	5			
Geological Literature.....	32	0	9			
Index to Quarterly Journal .....	75	0	0			
				1086	13	4
Investment in £2000 India 3 p. c. Stock						
at 104 .....	2082	13	0			
Ditto in £1295 Midland Railway 4 p. c.						
Perp. Pref. Stock at 141½ .....	1850	19	6			
				3933	12	6
Balance in Bankers' hands, 31 Dec. 1895..	835	5	10			
Balance in Clerk's hands, 31 Dec. 1895 ..	16	9	7			
				851	15	5

## 'WOLLASTON DONATION FUND.' TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', January 1st, 1895.....	22 10 5	Cost of striking Gold Medal awarded to Sir A. Geikie ..	10 10 0
Dividends on the Fund invested in 2½ per cent. Consolidated Stock .....	14 8 2	Award to Mr. W. W. Watts .....	19 4 6
Ditto Hampshire County 3 per cent. Stock .....	15 11 2	Purchase of £1073 Hampshire County 3 per cent. Stock at 105½ .....	1134 15 11
Repayment of one year's Income Tax under Schedule C..	19 9	Balance at Bankers', December 31st, 1895 .....	23 15 0
Sale of £1084 1s. 1d. Consolidated 2½ per cent. Stock at 104½ .....	1134 3 10		
Transfer from Geological Society .....	12 1		
	<u>£1188 5 5</u>		<u>£1188 5 5</u>

## 'MURCHISON GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', January 1st, 1895 .....	20 10 2	Award to Professor G. Lindström, with Medal .....	10 10 0
Dividends on the Fund invested in London and North-Western Railway 3 per cent. Debenture Stock .....	38 13 8	" Mr. A. C. Seward .....	28 10 0
Repayment of one year's Income Tax under Schedule C ..	1 5 10	Cost of Medal .....	17 0
		Balance at Bankers', December 31st, 1895 .....	20 12 8
	<u>£60 9 8</u>		<u>£60 9 8</u>

## 'LYELL GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
£	s. d.	£	s. d.
Balance at Bankers', January 1st, 1895 .....	53 2 8	Award to Rev. J. F. Blake, with Medal .....	35 0 0
Dividends on the Fund invested in Metropolitan 3½ per cent. Stock .....	68 0 4	" Mr. B. Harrison .....	17 0 10
Repayment of one year's Income Tax under Schedule C ..	2 6 8	" Mr. P. F. Kendall .....	17 0 11
		Cost of Medal .....	1 1 0
		Balance at Bankers', December 31st, 1895 .....	53 6 11
	<u>£123 9 8</u>		<u>£123 9 8</u>

## 'BARLOW-JAMESON FUND.' TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
	£ s. d.		£ s. d.
Balance at Bankers', 1st January, 1895 .....	38 17 3	Purchase of £468 Great Northern Railway 3 per cent. Debenture Stock at 110 $\frac{5}{8}$ .....	523 5 9
Dividends on the Fund invested in 2 $\frac{3}{4}$ per cent. Consolidated Stock .....	6 13 0	Balance at Bankers', 31st December, 1895 .....	52 15 0
Dividends on the Fund invested in Great Northern Railway 3 per cent. Debenture Stock .....	6 15 9		
Repayment of one year's Income Tax under Schedule C ..	9 0 0		
Sale of £500 2 $\frac{3}{4}$ per cent. Consolidated Stock at 104 $\frac{5}{8}$ ....	523 2 6		
Transfer from Geological Society .....	3 3 3		
	<u>£576 0 9</u>		<u>£576 0 9</u>

## 'BIGSBY FUND.' TRUST ACCOUNT.

RECEIPTS.		PAYMENTS.	
	£ s. d.		£ s. d.
Balance at Bankers', 1st January, 1895 .....	10 1 7	Cost of striking Gold Medal awarded to Mr. C. D. Walcott	11 9 5
Dividends on the Fund invested in 2 $\frac{3}{4}$ per cent. Consolidated Stock .....	2 15 8	Purchase of £210 Cardiff Corporation 3 per cent. Stock at 104 $\frac{1}{2}$ .....	219 16 3
Dividends on the Fund invested in Cardiff Corporation 3 per cent. Stock .....	3 0 11	Balance at Bankers', 31st December, 1895 .....	4 12 7
Repayment of one year's Income Tax under Schedule C ..	3 10 0		
Sale of £209 8s. 6d. 2 $\frac{3}{4}$ Consolidated Stock at 104 $\frac{5}{8}$ ....	219 2 3		
Transfer from Geological Society .....	14 0 0		
	<u>£235 18 3</u>		<u>£235 18 3</u>

W. T. BLANFORD, *Treasurer.*

## VALUATION OF THE SOCIETY'S PROPERTY ; December 31st, 1895.

PROPERTY.		£	s.	d.
Due from Longmans & Co., on account of Journal, vol. LI.				
etc. ....		62	8	1
Balance in Bankers' hands, 31 Dec. 1895 .....		835	5	10
Balance in Clerk's hands, 31 Dec. 1895 .....		16	9	7
Funded Property:—				
£2000 India 3 per Cents .....	2082	13	0	
£2250 London & North-Western Railway 4 per cent. Consolidated Preference Stock .....	2898	10	6	
£2800 London & South-Western Railway 4 per cent. Preference Stock .....	3607	7	6	
£500 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock .....	502	15	3	
£1295 Midland Railway 4 per cent. Preference Stock .....	1850	19	6	
Arrears of Admission-fees .....	69	6	0	
Arrears of Annual Contributions .....	110	0	0	
[N.B.—The above does not include the value of the Collections, Library, Furniture, and Stock of unsold Publications.]				
		£12,035	15	3
		£12,035	15	3

W. T. BLANFORD, *Treasurer.*

January 27th, 1896.

*Note.*—The investments in Stocks are valued at their cost price. Their aggregate selling-price on December 31st, 1895, at the quotations of the day, exceeds the above amounts by more than £1500.

## AWARD OF THE WOLLASTON MEDAL.

In handing the Wollaston Medal to Sir JOHN EVANS, K.C.B., D.C.L., F.R.S., F.L.S., Foreign Secretary (for transmission to EDUARD SUESS, Ph.D., For.Memb.R.S., For.Memb.G.S., Professor of Geology in the University of Vienna), the PRESIDENT addressed him as follows :—

Sir JOHN EVANS,—

May I request you in your official capacity, as Foreign Secretary, to receive and transmit to our esteemed Foreign Member, Prof. Eduard Suess, of the University of Vienna, this Medal, founded by that eminent man, Dr. Wollaston, in 1828, ‘to promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country, by whom such researches may hereafter be made.’ Of the 27 occasions on which this Medal has been transmitted to foreigners it has twice before been awarded to Austrian Geologists, namely, in 1857, to the illustrious Barrande, and in 1882, to Franz Ritter von Hauer, Intendant of the Imperial Museum of Natural History in Vienna and Director of the Geological Survey of Austria.

In speaking of a man so well known as Prof. Suess, words of commendation on my part are hardly needful. For 39 years he has occupied the Chair of Geology in the University of Vienna, and has exercised an influence on the work of the distinguished school of geologists in that city—including such men as Neumayr, Mojsisovics, Fuchs, Waagen, Penck, and many others—which proves him to be a great master of our science. Since 1851 a steady stream of Memoirs, issued by him, has proved him to be a great worker in Geology ; while the intellectual stimulus of his writings on foreign geologists shows him to be a great thinker. He is worthy of this Award, therefore, not only for the work which he has accomplished himself, but by what he has roused others to do, not only by the originality of his own thought, but by the extent to which he has influenced the minds of others.

Suess is not a specialist. He began work on Graptolites ; he next laid the foundations of the modern classification of the Brachiopoda and Ammonites. Alpine problems roused his interest in Dynamical and Structural Geology, and led to studies of the Austrian and Italian earthquakes, and to his suggestions of the connexion between these and the great circle of European Tertiary

Volcanoes and the elevation of the Alps. Work on the complex Tertiaries of the Vienna Basin and a study of the Mediterranean littoral geology led to his researches in Faunistic Palæontology, and so prepared the way for his pupil Neumayr.

Suess's varied knowledge, penetrative insight, and suggestive originality are perhaps best exhibited in his '*Antlitz der Erde*,' wherein he tried to show the main factors and methods that have ruled in geographical evolution.

The intimate union thus established between the problems of Geology and Geography cannot but be regarded as of the highest importance to the advancement of both sciences, and the world has been made wiser by the rich stores of knowledge which Prof. Suess has garnered for geologists and geographers in all countries.

Prof. Suess has been connected with this Society since 1863, in which year I made his personal acquaintance when he visited London. He has now been a Foreign Member since 1876, and is one of the three oldest foreign geologists on the Society's List. His attachment to this country will be better understood when it is known that Prof. Suess was born in London on the 20th of August, 1831, his father being at that time a merchant in the City.

I am sure it will add to Prof. Suess's pleasure to be told that this Medal was awarded him by the unanimous vote of the Council, and that we send, with it, our warmest remembrances and good wishes for his continued health and prosperity.

Sir JOHN EVANS, in reply, said :—

Mr. PRESIDENT,—

The recipient of this Award, whose professorial duties as well as his advancing age prevent him from attending this Meeting, has requested me to read the following communication from him :—

'By adding my name to the list of those Masters of Geological Science who have been honoured before me by the award of the Wollaston Medal, your illustrious Society renders me truly proud, and I can hardly find words adequate to express my feelings of gratitude.

'In addition to field-work, I have for many years laboured to obtain some approximately comprehensive view of the surface-structure



of the whole of our planet, and during this endeavour not a day has passed without bringing again and again before my eyes the vastness of the British Empire, the world-wide activity of British geologists and travellers, and the enormous amount of geological work and learning recorded in the English language.

‘I often and gladly remember the kindness and the instruction which during the course of my life I have received from my English masters, and above all from my repeated intercourse with Sir Charles Lyell, but I dared not think that my own modest essays would ever be deemed worthy of this distinction—the highest that English geologists can bestow.

‘This, however, now comes to me at an age when the natural diminution of physical strength confines me to valley and home; hammer and belt rest on their peg, and dreams and remembrances alone still carry me along those Alpine wanderings which form the highest charm of our incomparable science, and in the lonely grandeur of which Man feels himself more than ever a child of surrounding Nature.

‘In these hours of enforced inactivity, the Award of your Society leads me to hope that my past exertions have not been quite in vain; and with deepest thanks I receive this Medal as a token of indulgence, of encouragement, and also of consolation.’

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#### AWARD OF THE WOLLASTON DONATION FUND.

The PRESIDENT then presented to ALFRED HARKER, Esq., M.A., F.G.S., of the Geological Survey of Scotland, and of St. John's College, Cambridge, the Balance of the Proceeds of the Wollaston Donation Fund, addressing him as follows:—

Mr. HARKER,—

The Council request your acceptance of the Wollaston Fund in recognition of your admirable work in Petrology and your studies in the Metamorphic and Igneous Rocks and in Dynamometamorphism, to which you have given such careful attention since you joined our ranks as a Fellow in 1884.

I have only to allude to your papers before this Society on the Gabbro of Carrock Fell and its Granophyres; your petrological notes on rocks from the Cross-Fell Inlier; your paper on the

eruptive rocks of Sarn, Caernarvonshire; your joint papers with Mr. Marr on the Shap Granite and the associated Metamorphic Rocks,—to show the nature of the work in which you have been engaged.

Your Sedgwick Essay, on the Volcanic Rocks of Caernarvonshire, is a model of what such work should be. It has already received a well-merited encomium from your present chief, the Director-General of the Geological Survey.

In the past twelve years you have also been a frequent contributor to the pages of the 'Geological Magazine,' in which some twenty articles of yours are to be found.

Lastly, your excellent 'Petrology for Students,' issued from the Cambridge University Press last year, greatly adds to your credit in this field of research.

This slight recognition from the Council may serve to assure you how highly your past work has been appreciated, and how much more good work we trust that you will live to achieve.

Mr. HARKER, in reply, said:—

Mr. PRESIDENT,—

I heartily thank the Council for the honour which they have conferred upon me, and yourself for the graceful words with which you have accompanied this Award.

In the work to which you have made kind reference, I have confined myself to only one among the several lines of research recognized by this Society. I have, however, always regarded Petrology, not as a study apart, but as a branch of Geological Science; and whatever value may belong to my results, I owe in large measure to the fortunate circumstances which have enabled me constantly to combine work in the field with work in the laboratory.

Generous appreciation at the hands of those best qualified to judge is an incentive second only to the pleasure of the work itself. To the encouragement which I have at all times derived from the comradeship of fellow-workers, both at Cambridge and elsewhere, is now added that which must always attach to such an honour as the present one; and for the encouragement, no less than for the recognition, I tender my best thanks.

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## AWARD OF THE MURCHISON MEDAL.

In presenting the Murchison Medal to T. MELLARD READE, Esq., C.E., F.G.S., the PRESIDENT said :—

Mr. MELLARD READE,—

The Council of the Geological Society have awarded to you the Murchison Medal, in recognition of your work on 'The Origin of Mountain Ranges,' containing the records of much original and experimental research. Since you joined this Society in 1872 you have contributed to the various scientific Journals, and to this and other kindred institutions, more than a hundred papers on geological subjects, treating of 'the Geology and Physics of the post-Glacial Period in Lancashire and Cheshire,' 'the Buried Valley of the Mersey,' 'the Drift-beds of the North-West of England,' 'the Chalk-masses in the Contorted Drift of Cromer,' 'Tidal Action as a Geological Cause,' 'the Moon and the Earth,' and many other kindred subjects bearing upon Dynamical Geology, to which you have devoted much careful thought and originality of observation extending over more than a quarter of a century, and have never permitted an opportunity to slip of adding to our store of geological knowledge.

This Medal will serve to assure you that, although not often present at our Meetings, and living at a distance from town, you are neither overlooked nor forgotten by your fellow-geologists here, nor have your labours been unappreciated.

Mr. MELLARD READE replied as follows :—

Mr. PRESIDENT,—

It is with mingled feelings difficult, nay impossible, to express here, that I receive the Medal founded by the illustrious author of 'Siluria,' which the Council of this Society, in the exercise of their functions, have thought fit to award to me. If one circumstance more than another could add to the pleasure which the Award affords me, it is, Dr. Woodward, that I receive it through you as President of this Society. I cannot forget that my first little geological venture was launched in the columns of the 'Geological Magazine,' and that ever since you have proved to be a true and consistent friend.

As regards the work and researches of which you have so favourably spoken, it is for others to assess their value, and for me to

rejoice that they have been considered worthy of so handsome a recognition. Like the founder of this Medal, I began the study of Geology in middle life, and doubtless the direction and the character of my researches have been profoundly influenced by previous professional training as well as by natural bias. The study of Geology has been to me a labour of love as well as an interesting and healthful recreation. It has also been an education. Doubtless some of the work to which I have directed my attention has been of an arduous nature; but, as Shakespeare says,

‘The labour we delight in physics pain.’

It now only remains for me to thank the Council and yourself for this much appreciated recognition of my small services to Geological Science, and to assure you that the addition of my name to the distinguished list of Murchison Medallists is calculated to inspire and support me in any further work which in God’s providence I may be permitted to carry out.

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#### AWARD OF THE MURCHISON GEOLOGICAL FUND.

The PRESIDENT then presented the Balance of the Proceeds of the Murchison Geological Fund to PHILIP LAKE, Esq., M.A., F.G.S., addressing him in the following words:—

MR. LAKE,—

The Council of the Geological Society have awarded to you the Balance of the Proceeds of the Murchison Geological Fund, in recognition of your work in India, too soon interrupted by ill-health. Before you left, however, you had made a solid contribution to the history of the origin of the remarkable Laterites of that region (Mem. Geol. Surv. India, vol. xxiv. Art. 3, 1890), as well as to some other Indian geological problems. You have now commenced in Wales: first, in conjunction with Mr. T. T. Groom, at Corwen (Quart. Journ. Geol. Soc. 1893, vol. xlix. p. 426), and at a later date alone, near Llangollen (*ibid.* 1895, vol. li. p. 9), you have given the Society careful and accurate contributions on the Geology of these difficult regions.

Nor have you neglected Palæontological studies, as your recent paper on *Acidaspis* bears testimony.

It is hoped that this Award may prove not only useful, but that it may serve as an incentive to continued and important geological work in the near future.

Mr. LAKE, in reply, said :—

Mr. PRESIDENT,—

I am deeply sensible of the honour which the Council have done me in making this Award ; for to a labourer in the cause of science there is no truer pleasure than the appreciation of his labours by his fellow-workers. It is an additional gratification that it should fall to my lot to receive the Award at your hands, since of late I have attempted to follow in your footsteps in the field which you have made so peculiarly your own.

I feel, however, that the Award is a recognition far beyond what my work has hitherto deserved ; and I look upon it rather as an encouragement to persevere in the researches which I have begun.

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#### AWARD OF THE LYELL MEDAL.

In presenting the Lyell Medal to ARTHUR SMITH WOODWARD, Esq., F.L.S., F.G.S., the PRESIDENT said :—

Mr. ARTHUR SMITH WOODWARD,—

The Council of the Geological Society have awarded you the Lyell Medal, because it appeared to them that the Palæontological work to which you have so earnestly devoted your life since you commenced your career in the British Museum in 1882 would have met with the cordial approval of the distinguished geologist and writer who founded this Award.

Trained at the Owens College, Manchester, you had, besides this, an innate love of scientific work, and only needed the opportunity to develop into an accomplished palæontologist of the Vertebrata.

In dealing with the whole field of Fossil Vertebrata, you wavered at first between the varied groups to which your studies invited you ; but, after a few papers on Mammalia and Reptilia, you turned with a steady resolve to the study of Fossil Fishes, from which you have scarcely ever departed. More than one hundred papers on Fossil Fishes, besides a descriptive and illustrated Catalogue of Fossil Fishes in the British Museum, of which three volumes have already appeared (1889-95), and two Memoirs on the Fossil Fishes of New South Wales, attest the settled life-line of research to which you now stand committed.

But we have to thank you also for a joint work with Mr. C. Davies Sherborn, F.G.S., of the very greatest usefulness to palæontologists, 'A Catalogue of British Fossil Vertebrata,' 1890—a most trustworthy and excellent compilation, critically and carefully prepared.

That in the space of fourteen years you should have accomplished so much good work, is due to the fact that you have never wavered from the object which you had set before your mind to accomplish, and even in your numerous journeys in Europe and to North America you have ever kept your Ichthyological researches steadily in view.

I trust that this Medal, and the good wishes which accompany it from your friends here, will encourage you to the completion of your labours on the Fossil Fishes, and that the remaining group of the Teleosteans may enjoy the same careful and critical attention and study at your hands as you have bestowed upon the other and earlier groups.

Mr. SMITH WOODWARD, in reply, said:—

Mr. PRESIDENT,—

I desire to express my thanks to the Council of the Geological Society for the great honour that they have done me in making this Award, and to yourself, Sir, for the very kind and complimentary terms in which you have presented the Medal. During the last thirteen years I have merely tried to make the best use of the opportunities for research afforded by my official connexion with the British Museum; and the gratification experienced in the pursuit of duty of this kind is in itself so ample a reward for the labour involved, that a naturalist thus circumstanced scarcely looks for anything beyond it. When, however, the honourable marks of approbation officially bestowed are unexpectedly coupled with so highly esteemed a distinction as the award of the Lyell Medal by the Geological Society of London, I feel doubly encouraged to persevere and endeavour to merit the compliments that have been expressed.

I was first led to take a special interest in extinct Fishes by attending Dr. Traquair's course of Swiney Lectures on the subject in 1883. I was thus enabled to apply to this field of research the methods that I had previously learned from Prof. Boyd Dawkins when a student in the Owens College. Since that time the kindly encouragement of so many friends—yourself and the late Mr. William Davies among the foremost—has made progress easy; and the very

fortunate circumstance that most of the larger private collections of Fossil Fishes in this country have now been acquired by the British Museum, has afforded me favourable opportunities for study such as have never been enjoyed by any one previously. The biological problems suggested by these fossils seem to me to outweigh in interest the geological questions connected with them to so great a degree, that I have rarely been able to look upon them from any but a morphologist's point of view; and all the more on this account do I appreciate the high honour that is conferred upon me by the Geological Society to-day.

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#### AWARD OF THE LYELL GEOLOGICAL FUND.

The PRESIDENT then presented one-half of the Balance of the Proceeds of the Lyell Geological Fund to Dr. WILLIAM FRASER HUME, Assoc.R.S.M. & R.Coll.Sci., F.G.S., and addressed him as follows :—

Dr. HUME,—

Although for several years you have been actively engaged as a Demonstrator in Geology in the Royal College of Science, you have not allowed any opportunities for doing original work in the field to escape you; and your essay on the Chemical and Micro-mineralogical Structure of the several zones of the Upper Cretaceous rocks of the South of England illustrates admirably how such detailed work should best be carried out.

Your papers on the 'Black-Earth,' 'the Loess,' and on the Chalk of Russia, 'on the Genesis of the Chalk,' and on 'Oceanic Deposits,' indicate the bent of your researches towards the microscopic investigation of rocks—a line of study which Dr. H. C. Sorby, F.R.S., a past President of this Society, so profitably engaged in.

The Council hope, by the presentation of this Award, not only to mark their appreciation of your past researches, but to encourage you to extend them to other formations with the same useful results.

Dr. HUME replied as follows :—

Mr. PRESIDENT,—

At times a feeling of despondency has crossed my mind, when I

have considered the vastness of our subject, and the smallness of the contributions which I have endeavoured to add to our knowledge of the past; it is therefore a great encouragement to receive this mark of approval from those whose opinion we most value and esteem. It would, indeed, have been strange if, with the resources of the Royal College of Science at my disposal, I had not availed myself to the utmost of such exceptional opportunities.

Two facts afford me special gratification on the present occasion: the first, that this Award should be intimately connected with the great geologist whose historical and geographical methods I have been most anxious to follow to the best of my ability; the second, to receive it from you, seeing that you were the editor who piloted with friendly hand my first publication, at a time when it was especially in your power to damp or re-inspire the ardour of a young enthusiast. Therefore, to you, Sir, to the Council, and to the kind friends who have aided me by active counsel or friendly criticism, I hereby tender my most warm and hearty thanks.

The PRESIDENT then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to CHARLES W. ANDREWS, Esq., B.A., B.Sc., F.G.S., of the British Museum (Natural History), and addressed him as follows:—

MR. ANDREWS,—

Although your scientific career has been but a short one, you have lost no time in engaging in active and earnest studies in the Comparative Osteology of the Fossil and Living Vertebrata, and have already done some excellent work on the remains of the extinct gigantic Birds from Madagascar and from other parts of the world. Your papers on *Keraterpeton* from the Coal Measures, and on the Oxfordian genera of Plesiosauria, prove that you have already acquired an accurate knowledge of many points of detail in the structure of these extinct Reptiles which can only be appreciated by an equally careful study of existing forms.

In making this Award, the Council desire not only to assist and encourage you in the work which you have taken in hand with so much enthusiasm, but they have a confident expectation that you will ere long contribute papers to their Proceedings, which shall do honour to their prescience and bring κῆδος to yourself.



Mr. ANDREWS, in reply, said :—

Mr. PRESIDENT,—

I wish to express my sincere thanks to the Council for the great honour that they have done me, and to you, Sir, for the altogether too kind remarks that you have made. It was always my earnest desire to study the structure of animals, but in my wildest dreams I never hoped to have such opportunities as I now enjoy at the Natural History Museum, and I feel continually a sense of responsibility and fear lest I should prove unequal to the task which lies before me. Having now received this Award, I am still further bound in honour to do my utmost to justify it, and to fulfil as far as possible the expectations that you have expressed.

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#### AWARD OF THE BARLOW-JAMESON FUND.

In handing a moiety of the Barlow-Jameson Fund to Dr. G. J. HINDE, F.G.S. (for transmission to JOSEPH WRIGHT, Esq., F.G.S., of Belfast), the President addressed him as follows :—

Dr. HINDE,—

The Council have awarded the sum of Twenty Pounds from the Barlow-Jameson Fund to Mr. Joseph Wright, in recognition of the valuable services that he has rendered to the Palæontology, not only of the Carboniferous rocks in the South, but of the Cretaceous and Post-Tertiary deposits in the North of Ireland, and the Glacial deposits there, and in Scotland.

Mr. Wright is the author of numerous papers in the Transactions of the Belfast Naturalists' Field-Club, on the Irish Liassic and Cretaceous Foraminifera and other Microzoa; he has also prepared and published many lists of Foraminifera from the Scottish and Irish Boulder-Clay and other post-Tertiary deposits.

He has done much good work, extending over many years, when resident in the South of Ireland, in connexion with the fossils of the Carboniferous Limestone, and both as regards these, and the newer deposits of the North, his specimens have been always available to any one engaged in writing on the fossils. To Davidson, Rupert Jones, Holl, Brady, myself, and others Joseph Wright's cabinet was ever accessible and his specimens were freely lent for study.

I trust that this Award will serve to express to Mr. Wright our appreciation of his services, and will act as an incentive to him to continue his useful geological work.

Dr. HINDE replied as follows :—

Mr. PRESIDENT,—

It gives me great satisfaction to receive this Award on behalf of my friend Mr. Joseph Wright. He is unfortunately unable to be present, and has sent the following letter for communication to you :—

‘I desire to express my sincere thanks for the honour conferred upon me by the Council of our Society in recognition of my past work, and for their assistance in the further prosecution of my researches. Working so remote from the headquarters of the Society causes this Award to be the more appreciated.

‘I regret that I am prevented from being present to receive it in person, but I hope that the Council will accept this expression of my feelings regarding their approval of my work in a somewhat neglected field.

‘For some years past nearly all my spare time has been spent in microscopically examining the Glacial Clays for Foraminifera. My anticipation as to the occurrence of these organisms in Clays laid down under glacial conditions has been fully confirmed both as regards our local deposits and other British Clays, and I cannot avoid thinking that this fact must more or less influence our views as to the origin of these drifts.’

In handing to A. STRAHAN, Esq., M.A., F.G.S. (for transmission to Mr. JOHN STORRIE, of Cardiff), the second moiety of the Award made from the Barlow-Jameson Fund, the PRESIDENT addressed him as follows :—

Mr. STRAHAN,—

The Council have accorded to Mr. Storrie the sum of Twenty Pounds from the Barlow-Jameson Fund, in recognition of his services for the advancement of Geological Science while in charge of the Cardiff Museum, and, subsequently, as a volunteer worker on the Geology of South Wales. Mr. Storrie, I am informed, was the first to detect and describe an actual exposure of the base of the Old Red Sandstone near Rumney, and his researches have done

much to elucidate the obscure plant-remains from the Silurian rocks of that locality.

In the Rhætic and Triassic strata he found and fixed the exact horizon of certain fossils new to the district, while in the latter he made an interesting discovery of grains of gold. His intimate and accurate knowledge of the Cardiff area proved of great service to Geologists at the time when the British Association held its meeting in that town. Indeed few Geologists have worked in the neighbourhood of Cardiff without being indebted to him for assistance.

I have much pleasure in handing you this Award for transmission to Mr. Storrie.

Mr. STRAHAN, in reply, said :—

Mr. PRESIDENT,—

It will be a great pleasure to me to forward this Award to Mr. Storrie. The pages of our Journal testify to the value of the aid that he has rendered to many Fellows of the Society. I have myself been indebted to him for most valuable assistance in the geological mapping of the neighbourhood of Cardiff. Mr. Storrie writes to me :—

‘I regret that it will not be in my power to attend personally to thank the President and Council for the great honour that they have done me.

‘I am afraid that up to now I have not done enough to warrant my selection, but if ever I am able in future to do anything in the way of original work I shall be very anxious to justify this choice and give my whole mind to the accomplishment of the best work possible.

‘You will, I hope, convey in better words than I can the extreme gratitude which I feel for the Award.’

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## THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

HENRY WOODWARD, LL.D., F.R.S.

GENTLEMEN,—

The past year has left behind it a long and mournful record in our 'Street of Tombs,' and, as my own allotted time is so brief to-day, I would suggest that we should each entwine a garland of laurels and immortelles in memory of those whose names we honour, and so, hammer in hand, go forward.

Of aged Fellows, one, Robert Fitch, of Norwich, had reached his 93rd year. He was a contemporary of my father, Samuel Woodward, the Norfolk geologist, but twelve years his junior. Six Fellows and two Foreign Members—namely, Prof. C. C. Babington, the Ven. Archdeacon Browne, Sir E. H. Bunbury, James Carter of Cambridge, Mr. E. J. Chance, Gen. Copland-Crawford, Prof. J. D. Dana, and Prof. Sven Lovén—were between 80 and 90 years of age. Six Fellows and two Foreign Members—the Marquis de Saporta, Rt. Hon. T. H. Huxley, Prof. L. Rüttimeyer, the Hon. Walter Mantell, Mr. P. H. Lawrence, Mr. E. A. Wünsch, the Rev. E. Duke, and Mr. Richard Carter—were between 70 and 80 years of age. Eight Fellows—namely, Mr. J. W. Hulke, For. Sec., Mr. T. J. Slatter, Dr. J. E. Taylor, Mr. Charles Tyler, Rev. Lester Lester, Mr. J. Walter Tayler, Mr. W. S. Milnes, and Dr. G. W. Cline—were between 60 and 70. The remaining five were between 35 and 60:—Prof. Valentine Ball, C.B., Mr. J. Mitchell, Mr. G. F. Hosking, Mr. Hugh Miller, and Mr. J. E. Williams.

We have lost two Past Presidents: the Rt. Hon. T. H. Huxley, P.C., and Mr. J. W. Hulke, For. Sec.; four Foreign Members: namely, the Marquis de Saporta (France), Prof. J. D. Dana (United States of America), Prof. S. Lovén (Sweden), Prof. L. Rüttimeyer, M.D. (Switzerland); and one Foreign Correspondent, Sr. Don Antonio del Castillo (Mexico).

Three of these were also Wollaston Medallists. Another Wollaston Medallist died last year who was not a Fellow of this Society,—Prof. W. C. Williamson, F.R.S. (*æt.* 78). Williamson was distinguished as a palæobotanist, and was for many years Professor of Botany in Owens College, Manchester. His collection, illustrative of the structure of Fossil Plants of the Coal-Measures, has just been acquired by the Trustees of the British Museum.

The MARQUIS of SAPORTA, who was a Corresponding Member of the Institute of France, and a Foreign Member of the Geological Society of London since 1889, was born at Saint-Zacharie (Var) in 1823. He spent some time in a Jesuit college at Fribourg, and in 1861, in conjunction with M. Matheron, published his first paper on a palæobotanical subject, 'Examen analytique des Flores tertiaires de Provence.' From that date up to the time of his death, which occurred on January 26th, 1895, Saporta devoted himself, as a keen student, to the problems of his chosen science.

His earlier works dealt especially with the Tertiary vegetation of the South-east of France; the floras of Aix, Manosque, Sézanne, and other localities, have formed the subjects of elaborate monographs, in which he has not merely recorded lists of fossil species, but has dealt with the facts from a broad and philosophic standpoint. Between the years 1872-91 there appeared the splendid series of volumes on 'the Jurassic Flora of France'; this comprehensive work, with its numerous illustrations and exhaustive text, forms an indispensable handbook to students of Mesozoic Botany. Saporta's most recent work, on 'Upper Jurassic and Lower Cretaceous Plants,' appeared a few months before his death, 'Flore fossile du Portugal (Direction des Travaux géologiques du Portugal), 1895.' It contains a detailed geological and botanical analysis of an exceedingly interesting flora, and supplies fresh facts of considerable importance towards a more complete knowledge of the early history of dicotyledonous plants.

In addition to his numerous papers on palæobotany, Saporta has left such works as 'Le Monde des Plantes avant l'Apparition de l'Homme,' 'Origine paléontologique des Arbres cultivés ou utilisés par l'Homme,' and, in collaboration with Prof. Marion, 'L'Évolution du Règne végétal'; these form fitting memorials of his wide knowledge as a palæobotanist, and of his zealous advocacy of the importance of fossil forms to the student of plant-evolution. By some readers Saporta is perhaps best known as the too eager upholder of the claims of certain structureless casts and impressions to be included among fossil algæ. The valuable contributions to this subject by Nathorst have clearly shown how little weight must be attached to any speculations as to the development of plant-life based on Saporta's 'Algues fossiles' or his 'Organismes problématiques des anciennes Mers.'

As a contributor to Tertiary and Mesozoic botany, Saporta's name will always be associated with that of Heer and Ettingshausen;

and the later generation of workers in this branch of palæontology may well look upon him as a worthy pupil of Adolphe Brongniart, whose philosophic spirit and scientific handling of facts are reflected in the writings of his younger countryman. The writer of a recent obituary notice in a French scientific journal has thus happily expressed Saporta's unfailing industry: 'À des travaux considérables succédaient des entreprises plus considérables encore, et l'on oubliait l'âge en voyant l'œuvre s'augmenter et les horizons s'étendre toujours.'—[A. C. S.]

JOHN WHITAKER HULKE, F.R.S., President of the Royal College of Surgeons of England; Foreign Secretary of the Geological Society of London.

Only four days after the Anniversary Meeting last year, in the plenitude of his honours, and in the faithful discharge of his duties for the alleviation of suffering humanity, our late Foreign Secretary gave up his life. As senior surgeon he was summoned to Middlesex Hospital to perform an operation on February 7th, one of the most terribly severe nights of that exceptionally trying month; he returned home, fatigued and suffering from bronchitis, at 3.30 A.M., but attended and operated at the hospital on the 9th; visited his patients again on the 10th and 11th, when serious illness prostrated him, and he succumbed on the 19th February to pneumonia.

John Whitaker Hulke was born on November 6th, 1830, being the elder son of a well-known and widely respected general practitioner at Deal. The original family name was Hulcher, his ancestors being Dutch by origin, who had escaped from Holland during the Spanish persecutions under Philip II. and Ferdinand, Duke of Alva, and settled on the Kentish coast. There for some two hundred years they have followed the vocation of medicine. He was educated at King's College School, and at Neuwied, in Germany, and at the age of nineteen entered the medical school of King's College, where he was a dresser to Mr. (afterwards Sir) William Bowman, and house-surgeon to Sir William Fergusson. It was while he occupied this position that he attended the Duke of Wellington in his last illness, his father being the Duke's regular medical attendant and obtaining leave to avail himself of his son's services as assistant. In 1854, when the Crimean War broke out, he was early to volunteer, and at the beginning of 1855 was appointed assistant surgeon to the British Civil Hospital at Smyrna. Thence he was sent to Sebastopol, and in that awful campaign of

irremediable sickness, gross mismanagement, and gallantry as often as not ineffective, bore himself, in the opinion of everyone, with patient courage as a brave soldier.

On his return from the East he became medical tutor of King's College Hospital, and, having previously been elected a Fellow of the Royal College of Surgeons of England, was appointed, in 1858, assistant surgeon to Moorfields Hospital. He had previously been elected assistant surgeon to King's College Hospital, where, having duly served his allotted period, he was appointed, together with Dr. Charles Murchison, a colleague at King's, to the Middlesex Hospital, of which institution he was the senior surgeon at the time of his death.

Mr. Hulke's earliest mark was made in ophthalmology. He obtained the Jacksonian Prize of the Royal College of Surgeons of England for an essay on the Morbid Changes of the Retina; his treatise on the Use of the Ophthalmoscope (1861) formed an excellent introduction for most of the profession to the new system of intraocular examination; his Arris and Gale Lectures, delivered before the Royal College of Surgeons, and subsequently published, dealt with the Minute Anatomy of the Eye.

Mr. Hulke was elected a Fellow of the Royal Society in 1867, his claim being based exclusively on researches relating to the anatomy and physiology of the retina in man and the lower animals, particularly in the reptiles. These were embodied in two papers in the 'Philosophical Transactions' ('On the Anatomy of the *Fovea centralis* of the Human Retina,' and 'On the Chameleon's Retina'), and in a paper on the 'Retina of Amphibia and Reptiles,' in the first volume of the 'Journal of Anatomy and Physiology.' These are characterized by patient and conscientious minuteness in the working out and description of details, and cautious reserve in drawing inferences. Probably the most important and permanently valuable of Mr. Hulke's researches were those relating to the Retina of the Chameleon, which the abundant material at his disposal enabled him to elaborate in a more complete manner than had before been possible.

Mr. Hulke served on the Council of the Royal Society during 1879, 1880, 1888, and 1889; and was also a Member of the Scientific Relief Committee. His communications to the Transactions of that Society were numerous, and the last of them was read before it on May 12th, 1892—'On the Shoulder-girdle in Ichthyosauria and Sauropterygia.'

Very soon after he became a Fellow of the Royal Society Hulke

transferred his allegiance to geology, between which and his profession as a consulting surgeon his energies were thenceforth to be divided. Had he continued his anatomical studies he would without doubt have attained to the foremost rank among physiological anatomists.

During the quarter of a century which followed his first contributions to geological science, Mr. Hulke found leisure to apply himself to research in this field, notwithstanding his constantly increasing practice. He did so to so good a purpose that he became a palæontologist of no ordinary merit. His knowledge of comparative anatomy, and especially of osteology, enabled him rapidly to grasp the meaning of structures presented by the remains of fossil vertebrates; and this, combined with a naturally keen perception and a rigid adherence to facts, soon caused his opinion on palæontological matters to be sought, and held in the highest estimation.

It was the fossil Reptilia which more especially occupied Hulke's attention, and his numerous papers on their osteology are a monument to his industry. Many of the fossils which he described were, in part at least, freed from the matrix by his own facile chisel; and in this mechanical work, as he himself has said, he often found relaxation when his mind was overwrought by professional anxieties.

Mr. Hulke's well-earned vacations were often spent at localities of geological interest, more especially with a view to working out the fossils which might be obtained. For this purpose he paid frequent visits to Brook, in the Isle of Wight, whence have come many specimens of Wealden Dinosauria; near here also, at Brixton, was preserved the unique collection of these Wealden reptiles, made by the Rev. W. Fox. For many years Mr. Hulke was the only palæontologist who had free access to this collection; and he did much good work in bringing to light its hidden treasures, which would otherwise have remained almost unknown until after the death of the owner, when they were acquired by purchase for the British Museum.

In the year 1868, Mr. Hulke was elected a Fellow of the Geological Society of London, and from that time onwards the pages of the 'Quarterly Journal' of that Society were frequently enriched by his writings. No fewer than six of his papers were published in the two volumes which followed the year of his election, and these, with one exception, were descriptions of Saurian remains from the Kimmeridge Clay of Dorset. Several other papers on reptiles from the



same locality appeared in subsequent volumes ; but Mr. Hulke was more particularly interested in the Dinosauria, and many contributions to the osteology of this interesting group of reptiles have appeared in the 'Quarterly Journal' of the Geological Society, and in the 'Philosophical Transactions' of the Royal Society.

Our first knowledge of the cranium of *Iguanodon* was due to Mr. Hulke's work upon a specimen from the Isle of Wight, which completely revealed the brain-cavity, but, as it did not include the facial bones, its affinities were by no means easy to determine.

In 1873 and 1874 Mr. Hulke made additions to our knowledge of the small Wealden Dinosaur, which had been named by Professor Huxley *Hypsilophodon Foxii* ; and in 1882 a still more important memoir on the same species was published in the 'Philosophical Transactions.'

In 1874 and 1876 he showed that a certain bone of *Iguanodon*, which had been regarded as a scapula, was really a part of the pelvis ; and, indeed, it proved to be the remarkable pubis of that reptile, which so nearly resembles that of a bird.

In 1879 the two genera, *Poikilopleuron* and *Megalosaurus*, were proved by him to be one and the same Dinosaurian genus. In the same year he described the remains of a new Wealden Dinosaur under the name of *Vectisaurus valdensis* ; and in 1880 he made known one of the most perfect *Iguanodons* discovered in this country, obtained by Prof. (now Sir) Joseph Prestwich, from the Kimmeridge Clay of Cumnor, which he named *Iguanodon Prestwichii*.

In the following year there appeared in the 'Philosophical Transactions' Mr. Hulke's memoir on *Polacanthus Foxii*. This remarkable Dinosaur, the name for which had been suggested by Sir R. Owen, has a broad dermal shield spread out above the iliac bones in such a way as to form a kind of carapace over the lumbar and sacral regions ; besides this, large spines and scutes were attached to other parts of the animal's body.

Mr. Hulke's presidential addresses to the Geological Society, 1883-84, formed an important contribution to our knowledge of reptilian osteology, and especially threw light on the structure of the shoulder-girdle in Plesiosaurs and their allies.

The *Iguanodont*-remains found in England have been more or less fragmentary, and discoveries made by other workers which might serve to elucidate their structure were always hailed by Mr. Hulke with extreme satisfaction. No one more heartily

rejoiced than he did when the geologists of Belgium made known the discovery of the series of magnificently perfect *Iguanodon* skeletons, a facsimile of one of which now adorns the Museum of Natural History in Cromwell Road.

Mr. Hulke served for many years on the Council of this Society, and the high esteem in which he was held by the leading geologists of the day, as well as the thorough appreciation of his palæontological work, found expression by their electing him, in 1882, to fill the Presidential chair of this Society, and, in 1887, by presenting him with the Wollaston Gold Medal, the greatest honour that it was in the power of the Council to bestow. In 1891 he was elected Foreign Secretary of the Geological Society, which office he still held at the time of his decease.

Mr. Hulke left behind him a large series of most valuable specimens, mostly of Dinosauria, obtained with his own hands from the Undercliff in the Isle of Wight. This collection has been presented to the British Museum (Natural History) by Mrs. Hulke, in memory of her husband.

Lieutenant-General R. F. COPLAND-CRAWFORD, R. A., was elected a Fellow of the Geological Society of London in 1875, and died at his residence, Sunbury Lodge, near Wembley, Harrow, on March 5th, 1895, in his 85th year.

He was for many years a constant attendant at the Anniversary Meetings of the Palæontographical and Geological Societies, and his handsome, tall figure, military bearing, and his graceful method of proposing resolutions on such occasions will be remembered by many Fellows. He was not a writer, but a reader of geological literature.

Sir EDWARD HERBERT BUNBURY, Bart., was born in 1811, and educated at Trinity College, Cambridge, where, in 1833, he graduated B.A. (was senior classic and Chancellor's Medallist), and M.A. in 1836. Five years later he was called to the Bar of the Inner Temple, and was M.P. for Bury St. Edmunds from 1847 to 1852. He was elected a Fellow of the Geological Society in 1837, but does not appear to have communicated any paper to the 'Quarterly Journal.' Sir Edward Bunbury brought out his 'History of Ancient Geography' in 1879, and was a contributor to Sir William Smith's 'Dictionaries of Greek and Roman Biography and Geography,' especially the latter. He died on March 5th, 1895, in his 84th year.

ROBERT FITCH, F.S.A.—Geology, like other branches of Natural History, has owed much of its progress to the zeal of collectors. Of these, one of the most painstaking and successful was the late Robert Fitch, who, in addition to a most valuable collection of antiquities, had gathered together a very fine series of fossils from the Crag and Chalk of Norfolk. He was born at Ipswich, on October 21st, 1802, educated at the Grammar School, and apprenticed to a chemist and druggist in the town. Pursuing this occupation he settled at Norwich, in 1827, in partnership with Mr. Sheriff Chambers, and continued until he was over 90 years of age to take an active interest in business. From an early date he took great pleasure in fossils, and his specimens were always at the service of those engaged in palæontological studies.

He seldom wrote on geological subjects, his chief literary contributions being to the 'Transactions of the Norfolk Archæological Society.' In 1836, however, he communicated to the Geological Society an account of the discovery of the tooth of a *Mastodon* in the Crag at Thorpe, near Norwich; and in 1840 he sent to the 'Magazine of Natural History' a 'Notice of the existence of a distinct Tube within the hollows of the Paramoudra.' In later years he announced before the Norwich Geological Society the finding of Deer's antlers in re-deposited Chalk at Hartford Bridges, near Norwich; and also the discoveries of Flint Implements in the valley of the Little Ouse.

His fine collection is placed in a special room in the new Museum buildings at Norwich Castle. He died on April 5th, 1895, in the 93rd year of his age.

JAMES DWIGHT DANA was born in Utica, New York, on February 12th, 1813, and was educated at Yale College, where he graduated in 1833. On leaving Yale, he entered the service of the United States Navy as teacher of mathematics to midshipmen. In this capacity he visited, on board the 'Delaware' and the 'United States,' a number of the seaports of France, Italy, Greece, and Turkey, the cruise lasting fifteen months.

In 1836 he became assistant to Prof. Benjamin Silliman, the mineralogist, and in 1837 he published his 'System of Mineralogy,' a work which obtained a worldwide reputation, and which ran through numerous editions, of which the last was issued in 1892. Dana was next appointed Geologist to the Wilkes Exploring Expedition, which sailed in 1838, and returned in 1842. The

expedition consisted of five ships, the route pursued being briefly as follows:—First to Madeira, then to Rio Janeiro, down the coast and through the Straits of Magellan, after passing which, while on board the ‘Relief,’ he nearly suffered shipwreck off Noir Island, the ship remaining for three days and nights in extreme peril; in the same storm one of the smaller accompanying vessels was lost. Thence they sailed to Chili, Peru, and across to the Paumotu, to Tahiti, and the Navigator Islands; then to New South Wales, where the naturalists remained while Commodore Wilkes went into the Antarctic region; then to New Zealand and the Fiji Islands, where two of the officers were murdered by the natives; thence to the Sandwich Islands, the Kingsmill group, the Caroline Islands, and north to the coast of Oregon. Here, near the mouth of the Columbia river, the ‘Peacock,’ the ship to which Dana had been assigned, was wrecked, entailing the loss of all his personal effects, as well as many of his collections. He then made one of the party that crossed the mountains near Mount Shasta, and found their way down the Sacramento river to San Francisco. In his report of the expedition he states that the geological features indicated the probable presence of gold. This was six years before the discovery of gold in California, and rich mines have since been discovered in the region over which the party went. At San Francisco they were taken on board the ‘Vincennes’ and the homeward voyage was made by way of the Sandwich Islands, Singapore, the Cape of Good Hope, and St. Helena, arriving in New York in June, 1842. As a result of his connexion with the expedition he published the Reports on Geology, Crustacea, and Zoophyta, and spent in all thirteen years editing and superintending the printed reports resulting from these voyages. In 1855 he succeeded to the Chair of Mineralogy at Yale, a position which he held till 1894, when he resigned. His ‘Manual of Geology’ appeared in 1863, a fourth edition having been issued only last year, 1895. He was part editor of the ‘American Journal of Science’ from 1846, and continued his interest in it up to the last.

Dana received the Copley Medal from the Royal Society in 1877, and the Wollaston Medal from the Geological Society in 1872; he was a member of the Academy of Sciences, Paris, and of the Academies of Berlin and Munich. Moreover, he was elected a Foreign Member of the Royal Society in 1884, and of the Geological Society in 1851.

His publications amount to nearly 400 in number, and when one

considers that these include such colossal works as his 'Mineralogy' and his 'Manual' and 'Text-book of Geology,' one is astonished at Prof. Dana's wonderful power of work, nor is one surprised to learn that his health broke down upon several occasions owing to his excessive mental labours. It is extremely touching to read of Prof. Dana working on at the new edition of his 'Manual of Geology' at the age of 82, and being actively assisted in all his literary labours by his life-long companion with never-failing and watchful care to the end.

It is impossible to do justice to this distinguished man and personal friend in so short a notice, but we feel that, with our American brethren, we have lost in him one of the greatest figures in geology of our time. Prof. Dana died on April 14th, 1895, in his 82nd year.

It is hardly credible that a man could have attained to so high a position at once in zoology, in mineralogy, and in geology, and, from the specialization now rendered necessary by the progress of natural knowledge, we cannot expect to look upon his like again, nor to see united in one man attainments so varied in character as were those of the American veteran, James Dwight Dana.

As a man, he was noted for the gentleness and kindness of his character, so that he was always on excellent terms with all his colleagues. He leaves a widow and four sons and daughters.

MR. JOSEPH MITCHELL, Jun., Assoc.M.Inst.C.E., was born on September 7th, 1840. He was distinguished as a colliery engineer in the South Yorkshire district, several of the largest mines in the Barnsley district having been either sunk or re-opened by him. Among the latter may be noticed the Swaithe Main and Edmund's Main Collieries, re-opened and put in order after explosions, and of the former the Mitchell Main Colliery. A more important enterprise for the development of 2500 acres of the Barnsley bed at Grimesthorpe was commenced about six months before his death. Both as Secretary and President he contributed largely to the development of the Midland Institute of Mining, Civil, and Mechanical Engineers, and he was also very active in the formation of that most useful body, the Federated Institution of Mining Engineers. He was elected a Fellow of the Geological Society in 1873. His death occurred on April 18th, 1895.

VALENTINE BALL, C.B., M.A., and LL.D. (Dublin), F.R.S., M.R.I.A., Director of the National Museum at Dublin, was the second son of the well-known naturalist, Dr. Robert Ball, who died in 1857. His elder brother is Sir Robert Ball, of Cambridge, and his younger brother is Dr. Charles B. Ball, of Merrion Square, Dublin. Dr. Valentine Ball was born on July 14th, 1843, at No. 3 Granby Row, Dublin, a house well known in those days as a leading centre of intellectual resort in that metropolis. He was educated first at a private school by Dr. Brindley at Chester, and afterwards by Dr. Benson, in the early days of Rathmines School.

Valentine Ball entered Trinity College in 1860, and about the same time he was appointed by the later Master Fitzgibbon to a clerkship in the office of the Examiner in Chancery. His University career was not an eventful one in the academic sense, for the duties of his office in the Four Courts did not leave him sufficient time for more than obtaining an ordinary degree. A taste for scientific pursuits was, however, so marked that in 1864, when he was twenty-one years of age, he was appointed to the Geological Survey of India, then under the direction of Dr. Thomas Oldham. Ball felt that this would give him the opportunity which he wanted for the study of nature in a wide field, and accordingly he went to India. His duties as a geological surveyor often led him into very unfrequented parts of our Oriental possessions, and frequently, for many months together, he lived in camp in the jungle, apart from all other Europeans. Wherever Ball travelled he utilized his opportunities to the utmost; indeed, throughout his life, his diligence could hardly have been surpassed, and nothing worthy of notice that came within his range was unobserved and unrecorded. It was presently apparent that the young geological surveyor was not only able to fulfil his duties in making a careful investigation of the rocks and of their economic value, but that various other branches of natural history were sedulously cultivated by him.

Steadily the reputation of the Indian geologist advanced in scientific circles. He was elected a Fellow of the Calcutta University in 1872. He devoted a short vacation to extending his travels to the Andaman and Nicobar Islands, and to visiting Barren Island and Narcondam volcanoes in the Bay of Bengal, which he described in the 'Geological Magazine,' 1879, p. 16, pl. i.; 1888, p. 404; and 1893, p. 289, pl. xiii.

In 1874 Valentine Ball was elected a Fellow of the Geological Society of London. His first important volume, 'Jungle Life in

India,' gives a record of his travels and summarizes the results of his numerous papers. This work was followed by an elaborate treatise on the economic geology of India. His scientific reputation had by this time become so firmly established that, on the resignation of the Chair of Geology in the University of Dublin by the Rev. Dr. Haughton, Valentine Ball was appointed his successor. Thus was brought to a close his connexion of seventeen years with the Geological Survey of India.

In 1882 he was elected a Fellow of the Royal Society. In September 1883, Ball was appointed Director of the Science and Art Museum in Dublin, and resigned his Professorship in the University for the coveted post of Custodian of the new Museum, which he so ably and admirably organized, and to which he devoted the remainder of his life with unsparing energy and zeal.

Though his death was premature, yet it may be said that he had lived long enough to see the substantial completion of his life's task, the arrangement of the new Museum, which will long remain as a testimony to his work.

The University of Dublin conferred on him the honorary degree of Doctor of Laws, and by Her Majesty he was made a Companion of the Bath. With most of the scientific societies of Dublin Dr. V. Ball was in intimate association.

In 1879, he married the eldest daughter of the late John Stewart Moore, of Moyarget, Co. Antrim. He leaves a family of four young children. For some years Dr. Ball's health had been failing. Towards the middle of June serious symptoms became apparent, and he passed away peacefully on the afternoon of June 15th at his residence, 28 Waterloo Road, Dublin.

The only communications which Valentine Ball made to the Geological Society were 'On the probable Mode of Transport of the Fragments of Granite and other Rocks which are found embedded in the Carboniferous Limestone of the neighbourhood of Dublin,' *Quart. Journ. Geol. Soc.* vol. xlv. (1888) p. 371; and 'On some Eroded Agate-pebbles from the Soudan,' *Quart. Journ. Geol. Soc.* vol. xlv. (1888) p. 368.

In the Right Hon. THOMAS HENRY HUXLEY, this Society has lost one of its most distinguished Fellows, and the world of science one of its brightest ornaments.

He was elected a Fellow in 1856, was placed upon the Council in 1858, and in the same year was chosen to be one of the Secretaries,

filling that office till 1862. In that year, owing to the absence from England of the then President, Mr. Leonard Horner, Mr. Huxley drew up and delivered the customary Anniversary Address. He was a Vice-President in 1866; filled the office of President of the Society in 1868-69, and was again a Vice-President in 1871.

His first paper was read before the Society as early as 1856, and his last (on *Hyperodapedon Gordoni*) on May 11th, 1887, a period of 31 years, during which time he communicated 25 separate papers and three Presidential Addresses.

In 1876 the Society awarded him the blue-ribbon of our science, the Wollaston Medal.

Such is the record which Huxley has left us within these walls; but the energies he possessed, and the genius which inspired him, carried him into many other fields, and we cannot claim for ourselves more than a share in the life-work of this gifted and brilliant naturalist and scholar.

Thomas Henry Huxley was born at Ealing on May 4th, 1825, and was for some years educated at the School in his native place, where his father was one of the masters. This preparatory course was followed by assiduous private reading, including German scientific literature, and instruction in medicine received from a brother-in-law, who was a physician. He afterwards attended lectures at the Medical School of the Charing Cross Hospital. In 1845 he passed the first M.B. examination at the University of London, taking honours in anatomy and physiology. Even before this he had given evidence that his mind was occupied with something more than the technical details of the medical profession, for, while yet a student at Charing Cross Hospital, he had sent a brief notice to the 'Medical Times and Gazette' of that layer in the root-sheath of hair which has since borne the name of Huxley's Layer. After devoting himself for a short time to the practice of his profession among the poor of London, he, in 1846, joined the medical service of the Royal Navy, and was sent to Haslar Hospital. Here he did not remain long, but, like so many other men who have made their mark in biological science, set out on a voyage round the world.

Through the influence of the distinguished naturalist, Sir John Richardson, who had accompanied Franklin in his early Arctic expeditions, young Huxley obtained the post of assistant-surgeon on Her Majesty's ship *Rattlesnake*, then about to proceed on a surveying voyage to the Southern Seas. The ship sailed from England in the winter of 1846, and did not return until November,



1850. During the greater part of that time the *Rattlesnake* was employed in surveying the eastern and northern coasts of Australia and the coast of New Guinea. The seas lying between the Great Barrier Reef and the coast of the mainland were of special interest to the naturalist. Huxley took ample advantage of his opportunities to study the fauna of the seas which he traversed, with the results known to all naturalists. The communications which he sent home during the voyage made his name well known to the scientific world even before his return. Several of these were published in the 'Philosophical Transactions' of the Royal Society, and it is interesting to note that his first paper was presented to the Society by the then Bishop of Norwich (father of Capt. Owen Stanley, R.N., who commanded the *Rattlesnake*), and read June 21st, 1849: 'On the Anatomy and Affinities of the Medusæ.' Huxley in vain endeavoured to obtain the publication by the Government of a part of the work done during his voyage, and it was not until 1859 that his great work, entitled 'Oceanic Hydrozoa, a description of the Calyophoridae and Physophoridae observed during the voyage of Her Majesty's ship *Rattlesnake*, was given to the world.

The reputation which he had already attained at the early age of 26 is evident from the fact that in the year after his return, 1851, he was elected a Fellow of the Royal Society, and in 1852 was awarded one of the Society's Royal medals. In 1853 he left the Naval Service, and the following year, on the removal of Edward Forbes from the Royal School of Mines to the Chair of Natural History in Edinburgh, Huxley was appointed Professor of Natural History, including Palæontology, in that institution, a post which he held until his retirement at the age of 60—an age at which, as he was wont to assert, every scientific man ought to commit the happy despatch. In the same year, 1854, he was appointed Fullerian Professor of Physiology to the Royal Institution and Examiner in Physiology and Comparative Anatomy to the University of London. Other posts and honours crowded thick upon him. From 1863 to 1869 he held the Chair of Hunterian Professor at the Royal College of Surgeons. In 1862 he was President of the Biological Section at the Cambridge Meeting of the British Association, and eight years later held the Presidency of the Association at the Liverpool Meeting. In 1869 and 1870 he was President of the Geological and Ethnological Societies. As might be expected, Prof. Huxley held strong and well-defined views on the subject of education. He was a man who at all times had a keen sense of public duty, and it was

this which induced him to seek election on the first London School Board in 1870. Ill-health compelled him to retire from that post in 1872, but during his period of service as Chairman of the Education Committee he did much to mould the scheme of education adopted in the Board Schools.

He was elected Secretary of the Royal Society in 1873, and ten years later was called to the highest honorary position which an English scientific man can fill, the Presidency of that Society. During the absence of the late Prof. Sir Wyville Thomson with the 'Challenger' Expedition, Huxley, in 1875 and 1876, took his place as Professor of Natural History in the University of Edinburgh. From 1881 to 1885 he acted as Inspector of Salmon Fisheries. But this and all his other official posts he resigned in 1885, shortly after which he removed to Eastbourne.

During the 34 years that elapsed between his return from the 'Rattlesnake' voyage and his retirement from his various official posts, Huxley's activity as an investigator, as a writer, as a lecturer, as a citizen of London and of England, and as a man of healthy social instincts was incessant. There is hardly a department in the wide field of zoology, in its most comprehensive sense, in which he has not done original work. Huxley's investigations have explained many difficult problems in the mechanism of men and animals. So far as the character of his work is concerned, he is to be compared rather with Owen than with Darwin; though not only was the quality of his work more solid and enduring, but in many ways his type of mind was essentially different from that of Owen, more liberal, more open, free from what may perhaps be called the pettiness which hampered Owen's scientific vision. Huxley's investigations, it may fairly be said, especially after the publication of the 'Origin of Species,' were to a large extent guided by the Darwinian theory, and the results may be regarded as among the most substantial confirmations and illustrations of the doctrine of evolution as propounded by Darwin.

In the year before the publication of the 'Origin' he chose as the subject of his Royal Society Croonian Lecture 'The Theory of the Vertebrate Skull,' in which, so high an authority as Prof. Hæckel assures us, he first opened out the right track to a solution of a perplexing problem. Much of Huxley's technical work was published through the Royal Society, the Geological Survey, the Geological Society, and other media familiar to specialists, but seldom consulted—even by the educated general public. To give a mere list of these many memoirs would serve no purpose. Such important

subjects are dealt with as the Evolution of the Crocodilia, the Classification of Birds, the Dinosauria, Fossil Fishes, *Glyptodon*, the Affinity between Reptiles and Birds, *Ceratodus*, the Cranial and Dental Structure of the Canidæ, Reproduction and Morphology of *Aphis*, the Development of *Pyrosoma*. These few from among the titles of many memoirs will suffice to show that Huxley's special researches deal with the history and structure of animals of many types, and that by themselves they would justify the verdict of Ernst Hæckel that Huxley was the first zoologist among his countrymen. In this connexion may be mentioned his 'Manual of the Invertebrata,' his 'Lessons in Elementary Physiology,' and other text-books. 'When we consider the long series of distinguished memoirs with which,' to quote Hæckel, 'Prof. Huxley has enriched zoological literature, we find that in each of the larger divisions of the animal kingdom we are indebted to him for important discoveries. . . . More important than any of the individual discoveries which are contained in Huxley's numerous less and greater researches on the most widely different animals, are the profound and truly philosophical conceptions which have guided him in his enquiries, have always enabled him to distinguish the essential from the unessential, and to value special empirical facts chiefly as a means of arriving at general ideas.'

Huxley had a power of popular exposition almost unequalled. He could make plain, even to an ordinary working-man audience, the bearings of the most recondite researches of the zoologist and botanist; witness his famous Norwich lecture 'On a Piece of Chalk,' and the memorable sermon which he gave on a Sunday evening a quarter of a century ago in the midst of shocked Edinburgh. But it is not only to the ordinary intelligent reader that his numerous lectures, addresses, and magazine articles appeal. It is to these in their collected form that the special enquirer must go to find the broad results of Huxley's arduous scientific investigations. It was his duty when first he assumed his post in the School of Mines to give a course of lectures every alternate year to working men; and it was through this channel that he first made known his remarkable discussion on 'Man's Place in Nature.' This was one of the earliest and one of the most striking results of the publication of the Darwinian theory, for it was given to the world some ten years before the issue of Darwin's 'Descent of Man.' Even by those who maintain that influences have been at work in the development of Man, additional to those which have

been common to him and the lower animals, it may be said that Huxley's conclusions as to the intimate relations between humanity and the higher apes have been generally accepted. It was in the same 'popular' form that Huxley gave to the world many other theories and disquisitions which have had much to do with moulding educated opinion during the last quarter of a century. Thus in his three addresses as President of the Geological Society: on 'Geological Contemporaneity and Persistent Types of Life,' on 'Geological Reform,' and on 'Palæontology and the Doctrine of Evolution,' he dealt in his characteristically clear and masterly manner with problems that still agitate evolutionists—the imperfection of the record, the duration of geological time, the succession of life on the face of the earth, and other matters of profound interest to geologists and biologists. In his papers on 'The Methods and Results of Ethnology' and on 'Some Fixed Points in British Ethnology' he introduced into the somewhat chaotic branch of investigation that deals with Man a simplicity of treatment and a scientific method which have done much to raise it above a mere collection of unrelated facts. The lectures delivered in America in 1876 brought together the data as to the evolution of the Horse with a cogency that forms one of the most telling arguments in favour of the Darwinian hypothesis.

The only posts which Huxley continued to fill up to the time of his death were those of Dean and Honorary Professor of Biology in the Royal College of Science, South Kensington, Trustee of the British Museum, and President of the Palæontographical Society of London.

In 1892 he was admitted a member of the Privy Council, having previously refused the honour of knighthood.

It is impossible to enumerate here the many honours conferred upon Prof. Huxley. He was made a Doctor of the Universities of Edinburgh, Dublin, Cambridge, Oxford, Breslau, and Würzburg. The Academies of Brussels, Stockholm, Copenhagen, Cairo, Berlin, Göttingen, Haarlem, St. Petersburg, Lisbon, Rome, Munich, Philadelphia, and many others, conferred on him their diplomas. He was made an Honorary Fellow of the Royal Society of Edinburgh; a Member of the Royal Irish Academy; of the American Academy of Science; and (in 1879) a Corresponding Member of the Institute of France (Section Anatomy and Zoology, in place of Von Baer). He was also a Knight of the Polar Star of Sweden.

Turning to his published works, we may refer to his 'Oceanic Hydrozoa'; his 'Lectures on Comparative Anatomy and Physiology';

'Lessons in Elementary Physiology' (1866), and many subsequent editions; 'An Introduction to the Classification of Animals' (1869); 'Lay Sermons, Addresses, and Reviews' (1870). His text-books on the Anatomy (I.) of the Vertebrata (1871) and (II.) of the Invertebrata; his 'Practical Biology'; 'Man's Place in Nature'; his works on the Crayfish, and on Physiography, well illustrate the wide extent and versatility of his powers, both as a naturalist and author; but it was by his lectures and addresses that he displayed the most marvellous of his intellectual gifts, and produced the greatest effect upon the science of his time. He had that wonderful power of carrying his audience along with him, and the happy facility of bringing his knowledge within the mental grasp of his hearers.

Of the 144 papers attributed to Prof. Huxley in the Royal Society's list of scientific papers extending from 1847 to 1884, the following may be mentioned as directly connected with our own science:—

On the Method of Palæontology (Annals, 1856). *Pygocephalus Cooperi*, a Coal-measure Crustacean (Q. J. G. S. 1857). On the genus *Pteraspis* (Brit. Assoc. Rep. 1858). On *Cephalaspis* and *Pteraspis* (Q. J. G. S. 1858). On *Plesiosaurus Etheridgei* (Q. J. G. S. 1858). On Persistent Types of Animal Life (Roy. Inst. Proc. 1858-62). On Species and Races and their Origin (Roy. Inst. Proc. 1860). On *Stagonolepis Robertsoni* (Q. J. G. S. 1859). On some Amphibian and Reptilian Remains from South Africa and Australia (Q. J. G. S. 1859). On *Dicynodon Murrayi*, South Africa, and on Skulls of Dicynodonts (Q. J. G. S. 1859). On *Rhamphorhynchus Bucklandi*, a Pterosaurian from Stonesfield (Q. J. G. S. 1859). On a Fossil Bird and a Fossil Cetacean from New Zealand (Q. J. G. S. 1859). On Dermal Armour of *Crocodylus Hastingsæ* (Q. J. G. S. 1859). On the Anatomy of *Pterygotus* (Geol. Surv. Mem. 1859). On *Dasyceps Bucklandi* (Geol. Surv. Mem. 1859). On the Lower Jaw of a Labyrinthodont (Geol. Surv. Mem. 1859). On *Macrauchenia boliviensis* (Q. J. G. S. 1861). On *Pteraspis dunensis* (Q. J. G. S. 1861). Systematic Arrangement of Devonian Fishes (Geol. Surv. Mem. 1861). New Labyrinthodonts from Edinburgh Coal-field (Q. J. G. S. 1862). On a Stalk-eyed Crustacean from the Coal-measures, Paisley (Q. J. G. S. 1862). On the Premolar Teeth of *Diprotodon* (Q. J. G. S. 1862). On a New Species of *Glyptodon* (Roy. Soc. Proc. 1862-63). *Anthracosaurus Russellii*, Coal-field, Lanark (Q. J. G. S. 1863). On Cetacean Fossils termed '*Ziphius*,' Cuvier, from the Red Crag (Q. J. G. S. 1864). Osteology of *Glyptodon* (Phil. Trans. 1865). Vertebrate Remains from Jarrow Colliery, Kilkenny, Ireland (Geol. Mag. 1866). Dinosaurian Reptiles from South Africa (Q. J. G. S. 1867). On *Acanthopholis horridus*, a new Reptile from the Chalk Marl (Geol. Mag. 1867). New Specimen of *Telerpeton elginense* (Q. J. G. S. 1867). Animals intermediate between Birds and Reptiles (Geol. Mag. 1868). Two new Fossil Lacertilians from South Africa (Geol. Mag. 1868, pp. 201-205). On *Archæopteryx lithographica* (Roy. Soc. Proc. 1868). On *Hyperodapedon* (Q. J. G. S. 1869). On a new Labyrinthodont, *Pholiderpeton scutigerum*, from Bradford (Q. J. G. S. 1869). On the Upper Jaw of *Megalosaurus* (Q. J. G. S. 1869). Principles and Methods of Palæontology (Smithsonian Reports, 1869). The Milk-dentition of *Palæotherium magnum* (Geol. Mag. 1870). On *Hypsilophodon Foxii*, a new Dinosaurian from the Wealden, Isle of Wight (Q. J. G. S. 1870). Further

Evidence of the Affinity between the Dinosaurian Reptiles and Birds (Q. J. G. S. 1870). On the Classification of the Dinosauria, with Observations on the Dinosauria of the Trias (Q. J. G. S. 1870). Triassic Dinosauria ('Nature,' 1870, p. 23). On the Maxillæ of *Megalosaurus* (Phil. Mag. 1870). (With Dr. E. P. Wright) On the Fossil Vertebrata from the Jarrow Colliery, Kilkenny, Ireland (Roy. Irish Acad. Trans. 1871). On *Stagonolepis Robertsoni*, etc. (Q. J. G. S. 1875). On the Evidence as to the Origin of existing Vertebrate Animals (lectures, 'Nature,' 1876). The Rise and Progress of Palæontology ('Nature,' no. 24, 1881). The Coming-of-age of the 'Origin of Species' (1880, Roy. Inst. Proc. 9, 1882).

It may be truly said of Huxley that, although an antagonist to be feared, and a vigorous hater of all shams, he was also a warm-hearted and staunch friend, and one who never forgot a service rendered to him. The influence of his writings and his scientific labours will long outlive the memory of those who now mourn his loss.

CHARLES CARDALE BABINGTON, M.A., F.R.S., Fellow of St. John's College, Cambridge, was born on November 23rd, 1808, at Ludlow. He was a student at St. John's College, Cambridge, and graduated in 1832. In 1861 he succeeded Prof. Henslow in the Chair of Botany at the University. He retained his professorship until his death, on July 22nd, 1895, but for the later years of his life ceased to take an active part in the work of the Botanical School. Prof. Babington attained to the highest position as a critical British botanist, having an intimate and accurate acquaintance with the flora of our islands, and was the first to carefully correlate it with that of Europe.<sup>1</sup>

The best testimony of the value of his work is the fact that his 'Flora' has passed through eight editions in his lifetime, and still remains a standard work. In fossil botany his only contributions are the determination of some plants from the peat of Cambridge-shire.

He published 'A History of the Chapel of St. John's College, Cambridge,' and contributed many papers to the publications of the Cambridge Antiquarian and other Societies.

He was elected a Fellow of the Geological Society in 1835, but never contributed any paper to its Quarterly Journal.

THOMAS JAMES SLATTER, whose decease we have now to record, died at his house, 'The Drift,' Evesham, on August 1st, 1895, in his 61st year. He was a geologist whose knowledge of the locality

<sup>1</sup> See Babington's 'Manual of British Botany'; the first edition appeared in 1843, and the eighth in 1881.

in which he lived and worked was most intimate and reliable. He was born at Gloucester in 1834, while his family was for many years located at Stratton, near Cirencester. He was the cousin and intimate friend of John Jones, of Gloucester, whose contributions to geological literature are well known. Mr. Slatter commenced his business life, when quite a young man, in the Gloucestershire Bank, and then took up his abode at Evesham. He became successively manager of the Moreton-in-the-Marsh, Redditch, and Evesham branches of the Bank, but retired into private life a few years since, and, having erected a house on Green Hill, near Evesham, he removed thither his extensive and most interesting collection of Liassic fossils. In 1879 he became a Fellow of the Geological Society, but, to the regret of those who knew how careful an observer he was, he never became the author of any work on geology, nor even of any contribution to a periodical on the geology of the district which he knew so well.

GEORGE FRANCIS HOSKING, who resided at Bendigo, Otago, New Zealand, was elected a Fellow in 1891. He died at Dunedin, New Zealand, August 18th, 1895. He had not contributed any paper to the Society.

By the death of Mr. JAMES CARTER, F.R.C.S., which took place at Cambridge on August 31st, 1895, in his 82nd year, one of the few remaining links which connected the days of Sedgwick with those of the modern school of geology in Cambridge has been broken. During the greater part of his life Mr. Carter practised as a surgeon in Cambridge, where his house, in Petty Cury, was for many years the resort of the leading geologists and men of science in the University, who never failed to find in Mr. and Mrs. Carter genial, cultivated, and hospitable hosts.

Mr. Carter was especially interested in palæontology, and devoted much of his time to this and other scientific subjects. He contributed papers to the Geological Magazine and the Quarterly Journal of the Geological Society, the chief being 'On a New Species of *Ichthyosaurus* from the Chalk,'<sup>1</sup> 'On *Orithopsis Bonneyi*,'<sup>2</sup> 'On a Skull of *Bos primigenius* perforated by a Stone Celt,'<sup>3</sup> 'On the

<sup>1</sup> Brit. Assoc. Reports, 1845 (1846), Sec. p. 60, and Lond. Geol. Journ. 1846, vol. i. p. 8, woodcut.

<sup>2</sup> Geol. Mag. 1872, pl. xiii. f. 1, p. 529.

<sup>3</sup> Geol. Mag. 1874, p. 492.

Decapod Crustaceans of the Oxford Clay,'<sup>1</sup> and 'On Fossil Isopoda, with a Description of a New Species.'<sup>2</sup>

Mr. Carter was recognized as an authority on the fossil Podo-phthalmatous Crustacea, and had for some time been engaged in collecting materials for a monograph on that group; he has left his manuscript in an advanced state. He retained his interest in his pursuits almost till the last, and was engaged in his scientific work to within a few weeks of his death. He was elected a Fellow of the Geological Society in 1877. He served on the Councils of the Geological and Palæontographical Societies for some years, and was a local secretary of the latter society.

Mr. Carter presented his collection of Cambridge fossils to the Woodwardian Museum some years before his death.

SVEN LOVÉN, the eminent Swedish biologist, died at Stockholm, September 3rd, 1895. He was born in the same city on January 6th, 1809; his father was a wealthy merchant, who provided his son with an excellent education, the higher stages of which were carried on partly in the University of Upsala, and subsequently in that of Lund, where Lovén, in 1829, took the degree of Doctor of Philosophy. In the following year he studied zoology at Berlin under such teachers as Ehrenberg and Rudolphi, and then returned to Lund as Docent in Zoology. Several succeeding years were almost exclusively spent in studying the marine fauna, and more particularly the mollusca, of the western coasts of Sweden, and the field of his investigations was afterwards extended to the shores of the northern part of Norway and Finmark.

In 1837 Lovén sailed to Spitzbergen and inaugurated the first of the Swedish scientific expeditions to that island. Though his observations were mainly directed to the marine fauna of this region, the geological phenomena did not escape his observation, and he was the first to discover the Carboniferous strata of the island. He also obtained fossils from newer rocks, which proved to be in part identical with those from the Jurassic beds of Petchora Land, described by Keyserling, and thus established the existence of Jurassic deposits in Spitzbergen.

In 1839 Lovén supplemented his study of the molluscan fauna of the Arctic regions by visits to the Museums of London, Paris, and the principal towns of Germany. He thus fitted himself for the position of Intendant or Keeper of the Lower Invertebrata in

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xlii. (1886) p. 542, pl. xvi.

<sup>2</sup> Geol. Mag. 1889, p. 193, pl. vi. figs. 1-7.



the Swedish State Museum, with the associated title of Professor to the Academy of Sciences, to which he was appointed in 1841. He fulfilled the duties of this office for the long period of 51 years, retiring in 1892, when the natural infirmities of age disabled him from further service. One of the duties assigned to the Intendants of the Museum was the preparation of an annual report, including a record of the general progress in the particular branch of science to which each belonged; in doing this Lovén brought out a fairly complete report of the zoological and palæontological literature of the Lower Invertebrata for the years 1840-49, in three thick volumes. The great increase of scientific literature after this latter date would have needed all the time of the Intendant to keep a proper record of it, and therefore the obligation was abolished.

Lovén's repeated journeys across Sweden by way of the Göta canal, from Stockholm to Bohuslän on the west coast, gave him an opportunity of studying the geology of the country, and so intimately was he acquainted with it that (on Berzelius's recommendation) he accompanied Sir Roderick Murchison from Göteborg to Stockholm, bringing under his notice the best known Silurian localities in Eastern and Western Gotland. The friendship then formed was pleasantly renewed some ten years later, when he met Murchison and the late Prof. John Morris at Marienbad.

The critical knowledge possessed by Lovén of the Mollusca of the Arctic and North Seas enabled him to recognize the distinctly Arctic character of the shells in the Glacial deposits of Sweden, now elevated considerably above the sea-level. He first pointed out, in 1839, this evidence of the former presence of an ice-cold sea over parts of Sweden. Later on, in 1860, he published several papers on certain Crustacea and fishes, now living in the larger inland lakes of Sweden, which were shown to be the descendants of forms inhabiting Arctic seas, constituting a relict-fauna which had thus survived the changes of habitat and climate.

Lovén's researches on the Mollusca continued up to 1860; from then onwards to the close of his career, a period of over 30 years, his energies were devoted to the study of Echinodermata. His renown as a biologist will mainly rest on his magnificent work on the Echinoidea, as shown in the two principal memoirs '*Études sur les Échinoïdes*,' published in 1874, and '*On Pourtalesia*, a genus of Echinoidea,' in 1883. Among the authors who have most clearly illustrated the developmental history and the organic relations of the Echinoidea, Sven Lovén will stand in the foremost rank.

From his early days Lovén recognized the intimate reciprocal

connexion of zoology and palæontology ; this standpoint was steadily followed in his great work on the Echinoids, and he gave a practical expression of his views on this subject by arranging the fossil and recent representatives of this group side by side on the same shelves in the State Museum at Stockholm.

Both in his own country and abroad, Lovén was honoured as a master in natural-history research, and his amiable character and personal kindness endeared him to his colleagues and fellow-Academicians in Stockholm. He was chosen a Corresponding Member of the Institute of France in 1872, a Foreign Correspondent of the Geological Society in 1863, and a Foreign Member in 1882. He was further a Foreign Member of the Royal Society, and of the Academies of Berlin and Vienna. And lastly, in 1893, he received the Prussian Order 'Pour le Mérite.'<sup>1</sup> (G. J. H.)

The Hon. WALTER BALDOCK DURRANT MANTELL was the eldest son of Dr. Gideon Mantell, F.R.S., F.G.S., the well-known Sussex geologist and discoverer of the *Iguanodon*. He was born in 1820, and left England about 1840 for New Zealand, where he became a man of great public importance, holding the posts of Minister for Native Affairs, Postmaster-General, and Secretary for Crown Lands. He was ever mindful of the interests of the Maoris, and sought to serve them to the utmost of his power.

In 1847 Mr. Mantell sent home the first remains of *Notornis*. These were described by Owen as belonging to an extinct form, but two years later, in 1849, Mantell obtained from some sealers on the south coast of Middle Island (now called the South Island), where he was Government Commissioner for the Settlement of Native Claims), a skin together with the skull and some limb-bones of a *Notornis* recently hunted down with dogs, and killed and eaten by these men. Not long afterwards another smaller skin was obtained. Both these specimens are preserved in the Natural History Museum.

The bird was apparently unknown to the Maoris, but there are traditions of a 'Swamp-Hen,' called on the North Island 'Moho,' and in the South 'Takahé,' which may have been the *Notornis*.

In 1868 Mantell read a paper before the New Zealand Institute<sup>2</sup>

<sup>1</sup> For many of the data in the above notice the writer is indebted to the sympathetic notice of his late colleague by Prof. G. Lindström in *Geol. Fören. i Stockholm Förhandl.* Bd. 17, Häft 6, 1895, pp. 627-638.

<sup>2</sup> *Trans. New Zealand Institute*, vol. i. 1868.

‘On the Moa,’ in which he insisted that these birds were contemporaries of Man, their remains being found charred and broken in the Maori ovens, together with stone implements. He also discussed the cause of the extinction of the Moa, and ascribed it chiefly to the agency of man, a view now generally accepted.

In a later paper read before the Wellington Philosophical Society, 1872, he discussed statements that had been made, that Moa-bones had been found beneath marine deposits with extinct shells, and stated that this idea arose from a misapprehension of some information supplied by him to his father, who employed it in his paper before the Geological Society.<sup>1</sup> He also gave an account of some new localities in which Moa-remains had been found, including Waikonaiti and Te-Rangatapu. In the latter he obtained a large number of fragments of Moa-eggs, several of which he succeeded in restoring. Some of these specimens are now in the Natural History Museum.<sup>2</sup>

Mr. Mantell was elected a Fellow of the Geological Society in 1858. He died on September 7th, 1895, at the age of 75 years. He was in correspondence with Sir William Flower, at the time of his death, as to a further donation of his remaining private collection of Moa-remains to the British Museum, which it is hoped may still be made by his representatives at Wellington, New Zealand.

RICHARD CARTER, elected a Fellow in 1874, died on September 26th, 1895, aged 78, at Springbank, Harrogate, Yorkshire.

JOHN ELLOR TAYLOR, Ph.D., F.L.S.—As an enthusiastic lover of Nature, and a popular exponent of geological and botanical science, Dr. Taylor did much to arouse in others an interest in natural-history subjects. The son of the foreman of a cotton factory, he was born at Levenshulme, Manchester, September 21st, 1835, and was employed in early years in the railway-works at Crewe. Developing a taste for literature and science, he read largely, cultivated a facile style of writing, and became a contributor to a Manchester paper. His leisure hours were devoted to geology,

<sup>1</sup> See Quart. Journ. Geol. Soc. vol. iv. (1848) pp. 225–241. [The woodcut which gave rise to the misapprehension is probably that on p. 240.]

<sup>2</sup> See ‘Notice of the Remains of *Dinornis* and other Birds, and of Fossils and Rock-specimens, recently collected by Mr. Walter Mantell in the Middle Island of New Zealand. By G. A. Mantell. With Notes by E. Forbes, and Sketch-map and Notes by Walter Mantell.’ Quart. Journ. Geol. Soc. vol. vi. (1850) p. 319.

and in his first work, 'Geological Essays' (1864), he gave a sketch of the geology of Manchester and its neighbourhood. About the year 1862 he settled in Norwich, as sub-editor of the 'Norwich Mercury,' and stirred up much interest in the geology of the country round the old city. He drew attention to the disturbed Chalk at Whitlingham, Swainsthorpe, and other places; he pointed out the differences in the Mollusca preserved in the two shell-beds in the Norwich Crag at Bramerton; and, in conjunction with the late John Gunn, he established the Norwich Geological Society, which is now incorporated with the Norfolk Naturalists' Society. Before these local societies, and the British Association, the results of his geological observations were chiefly brought; and records of his work are printed in the earlier volumes of the Geological Magazine. In 1866 he published a little introduction to geology, entitled 'Lithographs,' and subsequently other popular works on natural history flowed from his pen. In 1872 he was appointed Curator to the Ipswich Museum, a post from which he retired through ill-health about two years ago. He contributed a capital 'Sketch of the Geology of Suffolk' to White's History of the county. For many years he was editor of 'Science Gossip'; while his science lectures at Ipswich and elsewhere were widely appreciated. Of late years he was a strong advocate of the search for coal in East Anglia. Dr. J. E. Taylor was present in the Geological Section of the British Association at Ipswich in September last, and spoke on the subject of the deep boring in search of coal at Stutton. He then definitely stated his opinion that, although unfavourable to the anticipations and hopes of himself and others, the boring had brought up a sample of the Yoredale Shales below the real Coal-measures. He died at Ipswich on September 28th, 1895.

The Rev. EDWARD DUKE, M.A., J.P., was elected a Fellow of the Geological Society in 1856. He was author of a book entitled 'Beneath the Surface, or Physical Truths, especially Geological.' He died at Lake House, near Salisbury, on Oct. 17th, 1895.

In Señor Don ANTONIO DEL CASTILLO, Director of the National School of Engineers, and of the Geological Survey of Mexico, America has lost a most able geologist, and the Geological Society a distinguished Foreign Correspondent. He was the author of a descriptive 'Catalogue of the Iron and Stone Meteorites of Mexico' (8vo, Paris, 1885), 'The Fossil Fauna of the Sierra de Catorce, San

Luis Potosi' (see Geol. Mag. 1895, p. 522), the 'Antropologia Mexicana,' 'El Hombre del Peñon' (Mexico, 1885, 8vo), also of numerous other memoirs and a large number of excellent geological maps. He died in Mexico city on October 22nd, 1895. He was in England at the Meeting of the International Geological Congress in 1888, and Commissioner for Mexico at the International Mining and Metallurgical Exhibition at the Crystal Palace, Sydenham. He was elected a Foreign Correspondent in 1891.

PHILIP HENRY LAWRENCE was born in Liverpool in 1822, and was admitted as a solicitor in 1848. He took an active part in forming the Commons Preservation Society, and acted as its solicitor until he ceased to practise in that branch of the profession. In 1872 Mr. Lawrence was called to the Bar at Lincoln's Inn. He had been elected a Fellow of the Geological Society in 1866.

He was the translator of Bernard von Cotta's 'Lithology,' a well-known handbook on rocks. Mr. Lawrence died at 8 Royal Crescent, Brighton, on October 17th, 1895.

Captain CHARLES TYLER, F.L.S., was born in London in August 1826, and was educated at University College.

He was a man of scientific tastes, an ardent microscopist, and a member of many learned societies. He joined the Microscopical Society in 1858, was elected a Fellow of the Linnean Society in 1862, and of the Geological Society in 1863. He served for many years on the Councils of the Palæontographical and the Ray Societies, and was for some time a member of the Honourable Corps of Gentlemen-at-Arms.

Capt. Tyler gave valuable assistance to Dr. Bowerbank in the examination of exotic sponges, when he was preparing his Monograph on the British Spongidæ for publication. He formed a large collection of fossils, and possessed many microscopes and a valuable collection of slides.

One of the chief interests of his life was his connexion with the Orphan Working School, Haverstock Hill, to which he devoted himself with characteristic energy and close personal attention during nearly forty years. During his later years he gave much attention to the administration of St. Thomas's Hospital, where he served repeated terms of office as Almoner.

Capt. Charles Tyler, who was in the 70th year of his age, died on November 2nd, 1895, after a short illness, which, however, was the climax of a long period of failing health.

E. A. WÜNSCH was one of the original members of the Glasgow Geological Society, which was founded in 1858, and served the office of Vice-President several times from 1858 to 1881, when he left Glasgow to reside at Carharrack, Scorrier, Cornwall. There he died on November 19th, 1895, aged 73 years. He was elected a Fellow of the Geological Society in 1875.

The most important service which he rendered to geological science was his discovery in 1865 of erect trees buried in volcanic ash in Arran. These trees were discovered in the Lower Carboniferous strata of the north-eastern part of Arran, in the sea-cliff, about 5 miles north of Corrie, near the village of Laggan. Here strata of volcanic ash occur, forming a solid rock cemented by carbonate of lime and enveloping trunks of trees, determined by Mr. Binney to belong to the genera *Sigillaria* and *Lepidodendron*. Sir Charles Lyell mentions that he visited the spot in company with Mr. Wunsch in 1870, and saw that the trees with their roots, of which about fourteen had been observed, occur at two distinct levels in volcanic tuffs, parallel to each other, and inclined at an angle of about  $40^{\circ}$ , having between them beds of shale and coaly matter 7 feet thick. It is evident that the trees were overwhelmed by a shower of ashes from some neighbouring volcanic vent, just as Pompeii was buried by matter ejected from Vesuvius.<sup>1</sup>

Mr. Wunsch writes<sup>2</sup>:—‘Trunks of trees 18 to 24 inches in diameter, and 2 to 3 feet in height, standing erect upon the original beds of thin coal and shale upon which they grew, and covered by layers of ash 2 to 3 feet in thickness, are found regularly dispersed over the area: while the ash overlying them, in which they are embedded, contains numerous branches, from 4 inches in diameter down to the minutest dimensions, some of the impressions displaying an almost feathery foliage, as though suddenly covered up before the vegetation had had time to decay, or become waterworn. The larger branches remain perfectly round, and show the pith in an admirable state of preservation; and the cellular tissue, filled up with mineral matter, is plainly visible to the naked eye.’

His last paper was ‘On a Logan-stone in the course of formation at St. Michael’s Mount,’ Trans. Roy. Geol. Soc. Cornw. 1895, pp. 605 & 669.

<sup>1</sup> Lyell’s ‘Student’s Elements,’ 4th ed. 1885, pp. 496–497.

<sup>2</sup> Geol. Mag. 1865, pp. 474–475; *ibid.* 1867, pp. 551–552.

Prof. Dr. LUDWIG RÜTIMEYER, Foreign Member of the Geological Society of London, was born at Biglen in the Commental, Canton Bern, in 1825. His father was a parish clergyman and afterwards Superintendent of the Orphanage at Bonn. Ludwig was educated in the High School and Gymnasium of that town, and in 1842 went to the University of Bern, where he studied theology, with the intention of following his father's profession. Having developed a taste for comparative anatomy, no doubt partly through the influence of his friend Peter Merian, the Basel palæontologist, he forsook his theological studies, and took up medicine. Afterwards he visited many of the chief European cities, and in Paris in 1850 he became acquainted with Élie de Beaumont. In 1852 he came to London, which he again visited in 1877. In 1854 he took up academical teaching in the Bern University, but in the following year he accepted the newly-established Chair of Zoology and Comparative Anatomy at Basel, which he held till his death.

On the occasion of his second visit to London he spent some weeks in a critical examination of the fossil *Bovidæ* from the Older Pliocene of the Siwalik Hills, India, part of the Falconer and Cautley Collection, preserved in the British Museum.

His first work, 'Vom Meere bis nach den Alpen,' was published on his return from his travels in 1854; after this he issued a long series of memoirs, characterized by the great accuracy and detail of their observations, and the wide philosophical grasp and far-reaching deductions made from them.

Some of the more important of these memoirs are:—'Untersuchungen der Thierreste aus den Pfahlbauten in der Schweiz,' 1860, in which he gives an account of the earlier races of some of the domestic animals, and shows that while in the Lake-dwellings of the Stone Age the remains of wild animals predominate (proving that the inhabitants lived mainly by the chase), in the later settlements, made after the use of metals was discovered, the inhabitants relied chiefly on various domesticated animals for food.

Another important paper is 'Beiträge zur Kenntniss der fossilen Pferde und zu einer vergleichenden Odontographie der Hufthiere im Allgemeinen,' 1863; this may be regarded as laying the foundation of that detailed comparative morphology of the teeth, in which the homologies of the several cusps are considered, and from which the American palæontologists have been able to draw very

important conclusions as to the phylogeny of many groups of mammals.

In a paper entitled 'Ueber die Herkunft unserer Thierwelt: eine zoogeographische Skizze,' 1867, Rüttimeyer gives a masterly account of the distribution of the mammalia, showing the relations of the fossil faunas to one another and to recent forms. It is a testimony to his sagacity that the great additions to our knowledge of this subject have confirmed most of his conclusions, and have rendered very few untenable.

He was elected a Foreign Correspondent of the Geological Society of London in 1877, and a Foreign Member in 1882.

Up to the time of his death Prof. Rüttimeyer maintained a lively interest in all scientific researches, and carried on his correspondence to the last. He died at Basel on November 26th, 1895.

The Ven. Archdeacon ROBERT W. BROWNE, M.A., Prebendary of St. Paul's, was elected a Fellow of the Society in 1833, and died at Wells on December 12th, 1895, in his 87th year.

The Rev. LESTER LESTER, who was elected a Fellow of the Geological Society in 1856, died on December 26th, 1895, at his residence, Langton Maltravers Rectory, Wareham, Dorset.

HUGH MILLER, F.R.S.E., was born on July 15th, 1850. He received his scientific education at the Royal School of Mines, being nominated thereto by Sir Roderick Murchison. Bearing the same name as his distinguished father, the author of 'The Testimony of the Rocks,' 'The Old Red Sandstone,' etc., Mr. Hugh Miller inherited with the name a taste for geological pursuits. He joined the Geological Survey in 1874, and was elected a Fellow of the Geological Society in the same year. Labouring at first among the Carboniferous Rocks and Glacial Drifts of Northumberland, he was subsequently transferred to the Geological Survey of Scotland, and worked at the Old Red Sandstone around Cromarty, rendered classic by the researches of his father. Later on he mapped portions of the Ancient Schists, Old Red Sandstone, and Drifts of Eastern Sutherland. Mr. Hugh Miller was taken ill at Lairg in December last, and died at his Edinburgh residence on January 8th, 1896, in his 46th year.

He was author of the picturesquely-written book entitled 'Landscape Geology,' and of papers on River Action and Glacial Phenomena. Among the more important of these papers the following



may be mentioned:—‘Tynedale Escarpments: their pre-Glacial, Glacial, and post-Glacial Features,’ 1880; ‘River-Terracing: its Methods and their Results,’ 1884; and ‘On Boulder-Glaciation,’ 1884.

All who enjoyed Mr. Miller’s friendship will feel that they have lost a kind-hearted, though keenly sensitive, friend. Strongly imbued with a love of Nature and natural phenomena, he at the same time kept himself in touch with the intellectual life of our time. He leaves a widow and a son, fifteen years of age, who is being educated at Fettes College.

JOSEPH WALTER TAYLER was elected a Fellow of the Geological Society in 1856. He was the son of the late Admiral Tayler, R.N., and made several expeditions to Greenland with the object of exploring the east coast and opening up again the old Danish settlements said to have formerly existed along its shores, but now completely blocked by the ice-pack. He was the discoverer of cryolite at Evigtok, Greenland (see *Quart. Journ. Geol. Soc.* vol. xv. 1859, p. 140), and gave an account of veins of tin-ore at Evigtok (*op. cit.* p. 606). He was an enthusiastic Arctic explorer, and gave to the Royal Geographical Society some interesting observations on the Greenland glaciers, which he had carefully studied.

FRANK JOHNSTON, F.C.S., was by profession an Assayer at the Rio Tinto Company’s Mines. He was elected a Fellow of this Society in 1884, and died at Tharsis, Huelva, Spain, in January 1895.

JOHN EVELYN WILLIAMS, M.Inst.C.E., was born on January 6th, 1845, and entered the drawing office of the Mersey Dock Estate, Liverpool, at the age of 14; there he remained for six years. He was afterwards engaged on dock- and harbour-works at Bristol, Hull, and Whitehaven. In 1877 he became Surveyor to the Witham Drainage Commissioners, and was actively engaged in the improvement of the drainage and harbours of one of the most important tracts of the Fenland until about a year before his death, having retired from that service in 1895. Mr. Williams was elected a Fellow of the Geological Society of London in 1880. Several important memoirs upon the work carried out by him have appeared in the Minutes of Proceedings of the Institute of Civil Engineers.

W. STERT MILNES was elected a Fellow in 1886. He died at Yeolmbridge, Launceston, Cornwall, in 1895.

G. W. CLINE, LL.D., was elected a Fellow in 1865. He resided at Allahabad, India, where he died.

EDWARD JOHN CHANCE, F.L.S., was elected a Fellow in 1837. He died at 14 Russell Square, W.C., in 1895.

Mr. FRANCIS EVERARD BROWN, Assistant-Clerk to the Geological Society, died suddenly from gastric ulcer on August 4th, 1895.

The Society loses in him an official whose unvarying patience, tact, and good-humour had made him deservedly popular among the Fellows, and whose scrupulous performance of his duties had earned him the respect and esteem of his official superiors.

He entered the Society's office in 1886, and had nearly completed ten years' service when his career of usefulness was brought to a close.

Always delicate in health even when a child, he was unable to indulge in those athletic sports with his schoolfellows which form the delight of most boys; and he was thus led early in life to take up the study of Natural History, and to make observations on animals and flowers. This developed in him later on a taste for scientific reading.

He collected autographs, took great interest in all matters connected with the fine arts, and had commenced to study and collect minerals and fossils.

Mr. Brown entered Messrs. Fulcher and Robinson's office when only 15 years of age, and afterwards was with Mr. Sims, a stock-broker, before he obtained his appointment at Burlington House. Here he speedily won the confidence of the Treasurer and Secretaries by his willingness and constant readiness and attention; whilst his uniform politeness to the Fellows and visitors speedily engendered a very kind and friendly feeling towards himself, which he retained to the end. He died at the age of 37 years.

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By the law of periodicity, which, happily, has a constant biennial limit, in this Society, I am about to vacate the Presidential Chair, in which you did me the honour to place me in 1894: but before doing so, and whilst I may yet claim the privilege of a few remaining sand-grains in Time's hour-glass, let me briefly draw attention to a few topics of general interest connected with our science, and in conclusion submit my second chapter on Crustacean life-history in later geological times for your acceptance.

As regards Home affairs we have just cause for satisfaction with our present financial position as a Society. Our income has not diminished, and we have a very respectable balance in hand, more than sufficient for our ordinary expenditure, and probably nearly sufficient to meet such extraordinary expenses as the installation of the electric light and the partial re-decoration of the Society's House.

It is satisfactory to find that the slight increase in our composition-fee for admission to the Society (decided upon in June 1894) has not acted as a deterrent to intending compounders, but that we have actually had more compounders during this last year than previously.

The completion of the 50 years' index has been somewhat retarded by the death of our valued and esteemed Assistant-Clerk, Mr. Francis E. Brown, which placed, for the time being, a heavy load of additional business responsibility on our Assistant-Secretary, who was happily equal to the emergency, and the Society suffered no serious inconvenience from the temporary vacancy in the staff.

The first number of 'Geological Literature added to the Geological Society's Library,' during the half-year ended December 1894 (8vo, pp. 58), was issued on the 1st May, 1895. On February 1st, 1896, a similar work was issued, covering the year 1895. It extends to 158 pp. (8vo), and will certainly prove extremely valuable to all workers in our science, particularly to Fellows in the country, desirous of knowing what our library contains of the latest geological interest.

The fifty-first volume of the Society's Journal, for 1895, compares favourably in every way with its predecessor.

Mr. E. T. Newton, F.R.S., announces the discovery of human remains from Palæolithic gravels at Galley Hill, Kent—which, if (in point of contemporaneous age) still involved in doubt, are yet of extreme interest to the student of Quaternary geology. Dr. G. J. Hinde and Mr. Howard Fox give a most interesting account of

the discovery of Radiolaria in the chert of the Culm-beds of Devon, Cornwall, and West Somerset; and Messrs. W. Hill and A. J. Jukes-Browne describe the occurrence of Radiolaria in the Chalk.

Mr. S. S. Buckman, in his paper on the Bajocian of the Mid-Cotswolds, records the results of a vast amount of detailed stratigraphical and palæontological work based upon the Ammonite and Brachiopod faunas of this area. Dr. J. W. Gregory treats of the Palæontology and Physical Geology of the West Indies. There are three papers on Madagascar: (1) by the Rev. R. Baron on the Geology of the Northern part of that island; (2) by Mr. R. Bullen Newton on the Fossil Mollusca; and (3) by Mr. R. Lydekker on a Sauropodous Dinosaur from the same region.

Prof. Amalizky contributes a paper on the Permian Freshwater Lamellibranchiata from Russia and South Africa; Mr. H. M. Bernard one on the Systematic Position of the Trilobites; and Miss J. Donald treats of British Carboniferous Species of *Murchisonia*.

I refer to these papers in order to express the hope that they may be taken to indicate (like the periodic variations in climatic conditions) a recent tendency in students of geology to turn towards palæontology, and not to entirely ignore her in favour of her sister petrology.

Thirty-four other papers deal with dynamical, petrological, physiological, and stratigraphical geology, in all quarters of the globe, and demonstrate the earnest and active interest which the Fellows of the Society take in the promotion of our science.

#### *The Geological Survey of the United Kingdom.*

In the early days of the Geological Survey my predecessors made a point of commenting on the annual progress made by that Institution, and remembering that some of the early fathers of the Society had a share in the establishment of the Survey, we may naturally feel a parental interest in its welfare.

Some years have now elapsed since any special Presidential remarks were made on the subject; a brief reference by Prof. Judd, a former member of the staff, appears in his address to this Society in 1887, but the latest general account of progress was given so long ago as 1868, by Sir Warrington Smyth, who, likewise an old member of the Survey, had in former years mapped some areas, and had in particular traced the course of many metalliferous veins in his capacity of Mining Geologist.

To note the special scientific results obtained by the Geological Survey has, however, during the past few years, been rendered unnecessary by the publication of the more detailed Reports of the Director General. It is the more desirable to draw attention to this fact, for the reports themselves, unless obtained in the form of reprints, are apt to lie buried in the more bulky General Report of the Science and Art Department. That Report must now be added to our record of Geological Literature, for in the elaborate statement of Sir Archibald Geikie we find many a new and interesting fact for the first time recorded, whether it relate to England or Wales, the Isle of Man, Scotland, or Ireland.

In parts of all these regions the Survey is actively engaged. The mapping of the Drift deposits in the Midland and Southern counties has been accompanied by important revisions of the more solid geology, and the results of the work are to be seen in the issue of sheets of the New Series of Ordnance Maps, geologically coloured, of parts of Sussex, the Isle of Wight, Hampshire, and Devon. The re-survey of the great coalfield of South Wales has already borne fruit in the shape of one new map and a sheet of vertical sections.

The progress of the 4-mile-to-1-inch map of England and Wales is of especial interest to us, as eventually it will replace our Greenough map, which was based on the original map of William Smith. Of the Survey map, which comprises thirteen sheets, seven are now published, five, we are informed, are being engraved, and one (the Isle of Man) will ere long be completed. A most important change has this year been introduced by the Director-General, that is, the issue of one of the sheets (that of the London Basin and great part of the Wealden area) printed in colours. Thereby the price has been reduced from 10s. 6d., that of the hand-coloured issue, to 2s. 6d.—a boon indeed to the geologist, and a course well calculated to ensure the wide circulation of the map.

Another departure made by the Director-General has been the preparation of Stratigraphical Memoirs, and of these one volume on the Pliocene Deposits, and five on the Jurassic Rocks have now been issued. In them our present knowledge from all sources is summarized, so that they may furnish stepping-stones to further progress.

In Scotland interest of late years has been centred in the resolute attacks made by the Survey on the problems connected with the Scottish Highlands. Following in the wake of Murchison, Nicol, and Lapworth, the officers in the field, headed by their

Director-General, have grappled with the difficulties and by dint of detailed work on the 6-inch scale have brought order into the structure of these complicated regions. Moreover they have demonstrated that in many respects the interpretation of Nicol, and the key furnished by the hard work of Lapworth, have been most successful in unlocking the secret of the Highlands. The maps which picture the results of the Survey work are probably the most elaborate that have ever been issued.

Elsewhere the Survey has been carried on among certain of the Western Islands in Skye, Raasay, and Rona, in Canna and Islay, and farther south in Arran.

In Ireland important revisions have been made in the older work, especially among the Palæozoic, the Metamorphic, and the Igneous rocks. The results may be studied in that excellent guide to the Survey Collections in the Dublin Museum which has lately been issued.

In noticing thus briefly the work of the Survey, I cannot avoid remarking on the notable accession made to the staff during the past eight years, of Teall, Lamplugh, Watts, Sollas, Gibson, and lastly of Harker.

Among these additions it will be noticed that a very strong Petrological element has been introduced into the Geological Survey—needful, however, in solving the problems connected with the ancient schists and other metamorphic rocks, and in elucidating the structure of our various igneous rock-areas.

Nor has Palæontology been neglected, in testimony of which we need only mention the papers by Mr. Peach in our own Quarterly Journal on the *Olenellus*-fauna of Scotland, and the new and strange forms of Reptilia lately described by Mr. E. T. Newton from the Elgin Sandstone—forms which are of world-wide interest.

The acquisition of scientific facts is, however, by no means the sole or main object of the Geological Survey. In the re-survey of our coal-fields the practical element is foremost, while in the London office all information that can be given is freely at the service of those interested in the industrial applications of geology.

By the death of Huxley the Palæontographical Society loses its President, an office which he had held since the death of Prof. Owen, its former President, in 1892.

But no change of Presidents can mar the useful and perennial flow of volumes issued by this evergreen Society, which has just

reached its Jubilee, and, like all successful and united people, it ought to celebrate the publication of its 50th volume in some suitable manner.

The 49 volumes already published are the joint labours of 46 authors, about 12 of whom have, however, achieved the greater share of the work produced. Prominent among these stand such names as Searles V. Wood, Richard Owen, Thomas Davidson, Edwards and Haime, F. E. Edwards, T. Rupert Jones, T. Wright, P. M. Duncan, H. A. Nicholson, G. J. Hinde, G. F. Whidborne, Salter, and others.

Very much of the success which has attended the Society must be attributed to the constant care and untiring energy of its Honorary Secretary, the Rev. Prof. T. Wiltshire, who has continually watched over the work and managed all the business details of the Society since he took over the duties from the first Secretary, Dr. Bowerbank, thirty years ago.

I feel that I should be wanting in gratitude to my many geological friends and supporters, did I omit, on this occasion, to thank them most heartily for the aid that they have always afforded me in carrying on the Geological Magazine for the past 32 years.

It is no easy task to arrange and get printed off 48 pages of matter on one special branch of science, and issue it regularly, with illustrations, for 380 consecutive months—but like other literary enterprises and institutions, ‘supported by voluntary contributions,’ we might well inscribe on the cover of the Magazine as our motto *Dominus providebit*; for, certainly, we have been singularly fortunate in our friends and supporters, amongst whom, in the past, as in this latter-day revival, we ought especially to remember the names of Prof. T. G. Bonney, Mr. W. H. Hudleston, and Dr. G. J. Hinde.

Through the death of Prof. Huxley, the Royal College of Science was deprived of its Dean and a Professor who had been connected with its teaching body for 41 years.

The office of Dean has since been conferred upon Prof. John W. Judd, C.B., LL.D., F.R.S., who succeeded Prof. Sir A. C. Ramsay in the chair of Geology in the then ‘Royal School of Mines’ in 1877, which was transfigured into the ‘Royal College of Science’ in 1881. Prof. Judd is a past President and Secretary of this Society, and we trust that he may long retain his deanery, to the advancement of the various sciences committed to his charge.

Sir Joseph Prestwich, D.C.L. (Oxon.), F.R.S., now in his 84th year, received the honour of knighthood from Her Majesty on New Year's Day. While we all heartily rejoice with and congratulate him and Lady Prestwich on the honour conferred, we cannot help feeling that the eminence to which he had long ago attained by his scientific labours far transcends such tardy recognition of his great and lasting services to geological science.

A rumour had reached me that our distinguished Foreign Member, Prof. James Hall, of Albany, who was elected on our Foreign list in 1848, and was Wollaston Medallist in 1858, had retired from his office of State Geologist of New York. I find this is not the case, the only change being that he has relinquished the post of Director of the Albany Museum since 1893, but he still holds the office of State Geologist. Thirteen imperial quarto volumes on 'the Palæontology of the State of New York' have been issued by Prof. James Hall, and, at the age of eighty-five years, he is still full of life and intellectual activity and engaged on a monograph on Fossil Sponges, the MS. of which is now nearly completed, with 30 quarto plates already drawn and lithographed.

We cannot but express our admiration for the marvellous energy and determination to carry on his work to the end, displayed by the illustrious Professor. In this country science has a more enervating and exhausting effect on Civil Servants, and they are deemed past work at sixty-five! Wherefore we are disposed to envy the happy lot of our old and valued friend.

Sir J. William Dawson, C.M.G., F.R.S., whose name will be always identified in this Society with his discoveries of air-breathing reptiles, land-snails, and myriopods, in erect, but hollow, trunks of trees, of Carboniferous age in the South Joggins Coal-field (Nova Scotia), and with his papers on *Eozoon* and 'Acadian Geology,' etc., held the office of Principal of McGill College, Montreal, since 1855, but has now retired into private life after a long and brilliant career. Sir William is still in full activity, and purposes to be at the Liverpool Meeting of the British Association this year. He received the award of the Lyell Medal in 1881. Sir William Dawson's Chair of Geology and Palæontology has been given to Prof. Frank Dawson Adams, M.A.Sc., Ph.D., F.G.S., a very able and promising geologist.

Another change has occurred in Canada by the retirement from office of our esteemed Fellow, Dr. Alfred R. C. Selwyn, C.M.G.,



F.R.S., from the post of Director of the Geological Survey of Canada; he had succeeded Sir W. Logan in 1869. He joined the English Survey in 1845, went out as Director of the Geological Survey of Victoria, Australia, in 1853, and was there through all the excitement of the opening up of the gold-fields of that colony. In 1869, he transferred his services to Canada, where he held office until 1894. Counting home and colonial service, Dr. Selwyn has been 49 years on active duty, and has served as Commissioner to three International Exhibitions. He received the Murchison Medal in 1876.

Dr. Selwyn has been succeeded as Director by Dr. George M. Dawson, C.M.G., F.R.S., F.G.S., eldest son of Sir William Dawson, who was on the North American Boundary Commission in 1873, and joined the Geological Survey in 1875. He has already served on several Royal Commissions, the last being that on the Behring Sea Fisheries; has made numerous communications to this Society, and was the recipient of the Bigsby Medal in 1891.

Dr. G. M. Dawson is one of the few individuals (of whom Sir Charles Lyell in 1864 was another instance) who may have read his own obituary, for his death was announced on November 12th, 1895, but was speedily contradicted by Sir Charles Tupper, High Commissioner for Canada, who cabled out at once and found that an error in the spelling of the name had changed *Lawson* into *Dawson*.

In our Indian Empire Dr. William King, B.A., who joined the Geological Survey in March 1857, and succeeded Mr. Medlicott as Director in 1887, retired from office on July 16th, 1894. During the 37 years of Dr. King's connexion with the Survey he published thirty-five papers, dealing mostly with the geology of the southern and central parts of India. He was succeeded on July 17th, 1894, by Mr. Carl L. Griesbach, C.I.E., F.G.S., who joined the Survey in Sept. 1878. Mr. Griesbach is the author of 26 papers on geology, from 1868 to 1893. He was employed on the Afghan Boundary Commission, from November 1884 to October 1886, and as Geologist to His Highness the Amir of Kabul, from January 1888 till July 1889. He has contributed some important work on the geology of the Himalayas, and received the gold medal from the Emperor of Austria in recognition of his services rendered in connexion with the scientific expedition in 1892 to the central regions of the Himalayas.

Another of our Fellows, Prof. John Milne, F.R.S., after spending

20 years at the Imperial College of Engineering, Tokio, Japan, and devoting his time and income to the investigation of earthquake-phenomena in that centre of remarkable disturbance, has now returned home from Japan and has established a station for seismological observations in the Isle of Wight.

Some of his latest researches on the propagation of earthquakes to great distances have led him to most interesting conclusions.

In the case of the Argentine earthquake of 1894 Milne was successful in showing that a large disturbance might be recorded at the antipodes of its origin. The pronounced movements of an earthquake travel over paths around an epicentre at a rate of 2 or 3 kilometres per second, and they are transmitted, at the same rate, to places distant more than a quarter of the earth's circumference. Preceding these pronounced movements which apparently radiate as quasi-elastic gravitational waves, minute tremors are observable, which, in travelling from Japan to Europe, apparently outrun the main disturbance by half-an-hour. The velocities at which these are propagated have been estimated as varying between 8 and 20 kilometres per second.

Assuming these determinations to be approximately correct, it is difficult to escape the conclusion that the motion, instead of having been transmitted through the crust of the earth, has been transmitted through its interior. Prof. Milne writes:—'When a number of properly-equipped observing-stations have been established around our globe, it seems likely that we shall be in a position to state definitely the velocity with which motion travels along paths at varying depths in the earth's interior. From the little already accomplished, it appears that, if our globe is capable of transmitting motion two or three times more quickly than steel, it has an effective rigidity very much higher than has hitherto been supposed.'

Thanks to these researches and experiments, carried out in coöperation with the late E. von Rebeur-Paschwitz and other observers in Europe, we may hope, possibly within a few years, to have a definite solution of what has heretofore been to geologists truly a *terra incognita*—the nature of the structure of the interior of the earth.

On his retirement in 1895, Prof. Milne received from the Emperor the well-merited decoration of the Rising Sun, in recognition of the valuable scientific work performed by him during his long residence in Japan.

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LIFE-HISTORY OF THE CRUSTACEA IN LATER PALÆOZOIC  
AND IN NEOZOIC TIMES.

In my Address, in February last year, I endeavoured to set before you as briefly as possible, an epitome of the more interesting points in the earlier chapters of the life-history of the Crustacea—a Class so ancient as to entitle it to take precedence over the whole of the Vertebrata, and probably over half the Invertebrata also, in the geological record.

From Lower Cambrian times to Carboniferous we showed that the Crustacea were mainly represented by the great and numerous order of the Trilobites, while bivalved Ostracods, huge Pod-shrimps (Phyllocarida) and giant Merostomata, such as *Eurypterus* and *Pterygotus*, with a few small King-crabs, fill up the picture of marine crustacean life.

To whatever part of the world we direct our gaze over the Palæozoic seas, the same group of organisms is more or less abundantly represented;—indeed it may be said that, until we reach the Upper Silurian, the Trilobites almost entirely occupy the primæval waters to the exclusion of other crustacean life. But from this stage upwards the Trilobites are more restricted, while the large Pod-shrimps, *Ceratiocaris*, appear in numbers, together with the gigantic *Pterygotus*, the latter attaining its maximum in the Old Red of Scotland.

Some 8 or 9 genera of Trilobites still continue on in the Devonian and the Carboniferous Limestone, in the latter formation reduced to about four genera, after which they disappear entirely.

Whether the Trilobites continued to live on in some of those marine areas which probably existed adjacent to the larger fresh-water and estuarine ones, amidst which the great subaerial growths of the Coal-period were being accumulated, we do not certainly know, but in the succeeding Permian epoch they have left no evidence behind.

As we scan the record of these old Carboniferous rocks, so rich in organic remains, we seem to stand on some lofty beacon-hill, whence we can cast our glance upwards and downwards along the stream of time. Beneath our feet lie buried the last representatives of those aboriginal races now quite extinct, the Trilobita and the Eurypterida, whose ancient hosts peopled the seas of Devonian and Silurian ages and some of whose predecessors reached far away to the Lower Cambrian epoch. Beside them lie the earliest representatives known of our modern Decapoda, Stomatopoda, and Isopoda, then but a few and feeble folk, but now the dominant races of the

Crustacean class. Is this then the great barrier-reef between the Palæozoic and Neozoic life-periods? Do we indeed find here the beginning of all modern forms of Crustacea and the ending of all ancient ones?—By no means; nor is there any period in the whole geological record at which a hard-and-fast line can be drawn dividing the earlier from the later members of any group.

Certain tribes, such as the Entomostraca, are represented throughout. Others, like the Amphipoda, may perhaps extend into Silurian times,—whilst Isopods and Decapods are probably represented as far back as in Devonian strata.

The Crustacea, in fact, bear testimony to the same general biological law which holds good in so many other classes of organisms, namely, that before one order dies out and disappears, other and successive groups have already made their appearance: the one overlapping the other in time.

There are, indeed, no sharp divisions in living Nature, but rather a subtle interblending of groups which, like the prismatic colours in the rainbow, shade off imperceptibly the one into the other.

**MALACOSTRACA.**—Throughout the sub-class MALACOSTRACA, to which so large a proportion of the Mesozoic, Cainozoic, and Recent forms of Crustacea belong, the number of segments present is generally very persistent for the three divisions of the body (head 6, thorax 8, and abdomen 7=21). They fall naturally into two groups, (1) the EMBRIO-PHTHALMA, in which the eyes are sessile, and (2) the PODO-PHTHALMA, in which they are pedunculated.

**AMPHIPODA.**—In the Amphipoda belonging to the first of these divisions, with sessile eyes, the body is pretty constantly and regularly developed, the small cephalothoracic head-shield only covers its own series of seven paired appendages, while the thorax and abdomen have usually each their proper and normal series of seven free somites, with a corresponding pair of limbs attached to each segment.

Most of the members of this order are of small size, with a laterally compressed body; but their numbers are almost incredible, and they are most widely distributed not only in freshwater lakes and rivers, springs and subterranean watercourses, but they are found living along the shores of almost every land in the open air<sup>1</sup> and also between high and low tides.

<sup>1</sup> Some species of *Orchestia* are known (as *O. tahitiensis*, *O. telluris*, *O. sylvi-cola*) which live far removed from the sea and at elevations of 1000 feet.

In 1870 I described what I believe to be a portion of a fossil Amphipod from the Lower Ludlow Rocks of Leintwardine, Shropshire, under the name of *Necrogammarus Salweyi*; it is not quite certain whether *Gamponyx fimbriatus*, Jordan, from the Coal-Measures of Rhenish Prussia, is correctly assigned to this division, but I am inclined to retain it here, however, as its most natural position. Mr. Spence Bate has named and described a species of Amphipod as *Prosoponiscus problematicus*, from the Magnesian Limestone of Durham.

Other fossil forms occur in the Tertiary rocks and are mostly referable to existing genera such as *Gammarus*, *G. cœningensis*, from the Miocene of Eningen; and *Palæogammarus sambiensis*, from the Baltic amber deposits, etc.

ISOPODA.—This division of the Malacostraca is marked by the persistence of the seven pairs of ambulatory thoracic limbs, which never bear the gills attached to their bases as in the Amphipoda, but the appendages of the abdomen take on this function, being specially modified into leaf-like branchial organs and do not take part in locomotion, save in the swimming forms. The members of the group are for the most part of small size. Many of the living Isopods are attached to fishes and crustacea, and one parasitic fossil form is known (*Bopyrus*).

Numerically, the order is large and very widely distributed geographically, consisting of walking, running, and swimming forms; and lastly of sedentary parasitic forms—of these it is the female only which remains fixed, the male being often peripatetic in his habits, passing from female to female. Many Isopods—*e. g.* the Oniscidæ—live habitually on land, breathing air, which it is necessary should be fairly moist; hence they usually frequent damp situations, under decaying wood and leaves, and beneath stones. The Sphæromidæ frequent rocky shores, and run and swim with considerable agility. Many forms of Isopoda are strictly marine, some occurring at great depths (over 2000 fathoms). Some few Isopods have been met with of larger size than the average members of the group. One, dredged by Prof. Alexander Agassiz, during the cruises of the 'Blake,' from a depth of 955 fathoms on the north-east of the bank of Yucatan, and north of the Tortugas, named *Bathynomus giganteus* by Alph. Milne-Edwards, measures 9 inches in length by 4 in breadth, and far exceeds any other living species in size. Notwithstanding the vast depth from which *Bathynomus* was obtained, the eyes are well developed, but instead of being placed upon the upper surface of the head as in all known wandering Cymothoidæ,

they are placed below the frontal border of the head, at the base of the antennæ.

I formerly entertained a very strong conviction that it would be possible to show the derivation of the Isopoda by direct descent from the Trilobita; but the former have so very constant and definite a number of 21 body-segments—as indeed is the case in the Malacostraca generally—(namely, 7 somites in the head, 7 in the thorax, and 7 in the abdomen), whereas in the Trilobita (as is the case with the Entomostraca generally) the number varies greatly, from 4 or 5 up to 28 somites in the body, that I feel I must recant and give up this heresy at once, lest I should be excommunicated by some later Carcinologist, and my effigy and papers burnt, if not my person.

It is probable that the Isopoda date back to the Devonian, for I have, in 1870, described, under the name of *Præarcturus gigas*, a form which appears to be a portion of a huge Isopod from the Old Red of Rowlestone, Herefordshire.

Portions of similar large Arthropods, which have been named *Arthropleura ferox*, by Salter, and *A. armata*, by Jordan, have been obtained from the Coal Measures of Manchester, of Fifeshire, of Radstock, Somerset, and from Saarbrücken, Rhenish Prussia, so that we may justly hope soon to obtain a fuller knowledge of the true characters of this remarkable animal.

The anomalous form, known as *Bostrichopus antiquus* (Goldfuss) from the Devonian of Nassau, may perhaps be placed here, as possibly related to the Munnopsidæ.

Several species of *Palæocaris* (*P. scoticus*, *P. Burnettii*, and *P. typus*) have been described from the Coal Measures of Manchester, of Scotland, of Bohemia, and of Grundy County, Illinois, U.S.A.; from this last-named locality another genus, *Acanthotelson Stimpsoni*, closely resembling *Palæocaris*, has also been obtained by Messrs. Meek and Worthen. These larva-like forms were relegated, by the late Prof. J. D. Dana, to a group holding an intermediate position between the typical Isopoda and the Amphipoda, for which he proposed the name 'Anisopoda.'

*Isopodites triasicus*, Picard, from the Muschelkalk of Thuringia, is somewhat doubtful. An undoubted *Sphæroma*-like Isopod, from the Great Oolite of Northampton, has been described by me under the name of *Cyclosphæroma trilobatum*, in 1890.

The Lithographic Stone of Solenhofen, Bavaria, has yielded two genera of Isopodous Crustacea, described in 1839 by Count Münster,

and named *Urda* and *Reckur*. A third Solenhofen form has been more lately described by von Ammon as *Ægites Kunthii*.

The well-known and abundant *Archæoniscus Brodiei*, of Westwood, described in 1845, from the Purbeck of the Vale of Wardour, Wiltshire, closely resembles existing members of the family Oniscidæ, to which it probably belongs. Mr. Westwood added another species, *Archæoniscus Edwardsi*, from the Lower Purbeck of Durdlestone Bay, Dorset, in 1854.

We owe to Prof. Bell the discovery of the parasitic Isopod, *Bopyrus*, beneath the carapace of *Palæococystes*, from the Cambridge Greensand, in 1862. The females of similar forms infest the carapaces of the common Prawn around our coasts at the present day.

*Palæga Maccoyi*, Carter, is from the Upper Greensand of Cambridge, and *Palæga Carteri*, H. Woodw., from the Grey Chalk of Dover. *Cymatoga Jazikowi*, Eichwald, from the Chalk of the Volga, completes the series of Cretaceous Isopods. Nearly allied to *Palæga Carteri* is *P. scrobiculata* from the Lower Oligocene of Haring, Tyrol.

The Eocene of the Paris Basin and the Isle of Wight has yielded four species of the genus *Eosphæroma*<sup>1</sup>; *Sphæroma Catulloi* is from the Eocene of Italy; and one occurs in the Miocene of Bonn. Sismonda, in 1846, recorded and figured a *Sphæroma* (= *Palæga*) *Gastaldi* from the Miocene of Turin; and Oswald Heer a species of Woodlouse (*Armadillo molassicus*) from the Miocene freshwater strata of Oeningen. Five others (*Cymodocea sarmatica*, Andr.; *Sphæroma exors*, Eichw.; *Sph. faveolatum*, Costa; *Palæga anconitana*, Andr.; *Archæosphæroma Fricii*) are all Newer Tertiary forms.

A species of *Oniscus*,<sup>2</sup> a *Trichoniscus*, and three species of *Porcellio* are all described from the Amber-deposits of Tertiary age on the Baltic coast; and a fossil *Sphæroma* (*S. Burkartii*) has been described from Mexico by M. Barcena.

PHYLLOCARIDA and CUMACEA.—Standing on the border-line between the Malacostraca and Entomostraca are the PHYLLOCARIDA, represented at the present day by the genus *Nebalia*, which affords a connecting-link between the Phyllopoda and the Malacostraca (see my previous address, Feb. 15th, 1895, pp. lxxxiii & lxxxiv).

In the earlier of these ancient Silurian 'Pod-shrimps,' such as

<sup>1</sup> Namely, *Eosphæroma Smithii*, *E. fluviatile*, H. W., *E. Brongniarti*, Edw., *E. obtusum*, H. von Meyer.

<sup>2</sup> Namely, *Oniscus convexus*, Koch, Tertiary amber-deposits, Baltic. *Trichoniscus asper*, Menge, loc. cit. *Porcellio notatus*, Koch, *P. granulatus*, Menge, *P. cyclophorus*, Menge, loc. cit.

*Ceratiocaris papilio*, *C. stygia*, and *C. Halliana*, the carapace is large and is composed, as in the living *Nebalia*, of a reduplication or fold of the dorsal integument of the head-segments, which stretches backwards and forms a separate cover or shield, not only to the cephalic and thoracic segments but even to some of the abdominal ones as well.

In some of the later forms, more particularly in species like *Ceratiocaris scorpioides* and *C. elongatus*, described and figured by Mr. B. N. Peach, F.R.S., from the Lower Carboniferous rocks of Eskdale, the carapace is quite small and only about one-fourth the length of the body, leaving about 10 segments of the slender thorax and abdomen exposed to view.

This is precisely what one sees in the living forms of the genera *Cuma*, *Bodortia*, *Diastylis*, etc., and one is led to the conclusion that we have here, in all probability, a passage upward from the more ancient Phyllocarid type (in which a larger expansion of the head-shield and a larger number of post-cephalic segments exist), to the more modern Cumacea (in which only a small dorsal shield is developed, formed partly by connecting some of the anterior thoracic terga with those of the head), and thus gradually leading up to the Decapoda (in which all the thoracic terga unite with the head to form a true cephalothoracic carapace as in *Astacus* and *Homarus*).

PODOPHTHALMA.—1. The STOMATOPODA—represented at the present day by *Squilla* and five other genera—are of especial interest to us as, they offer so many important points of difference in their structure from other adult crustacea. It is in this sub-order that the typical number of 21 segments can always be distinguished. The carapace is quite small, and only covers a part of the cephalothorax, while the gills are carried exposed in tufts attached to the abdominal swimming-feet. The second maxillipeds—usually small mouth-organs—are developed in *Squilla* into a pair of large and powerful raptorial claws, taking the place of the chelate limbs of the common lobster and crab.

From their extensive distribution over the seas of the globe, their past life-history and high antiquity, the Stomatopoda justly challenge the attention of the palæontologist.

They make their appearance as far back in geological time as the Coal Measures<sup>1</sup>—one species, *Necroscilla Wilsoni* (H. Woodw.),

<sup>1</sup> There is a doubtful form (*Amphipeltis paradoxus*), Salter, occurring in the Devonian of St. John, New Brunswick, which may belong to the Stomatopoda.



having been met with in the Middle Coal Measures of Cossall, near Ilkeston, Derbyshire, by Mr. Edward Wilson, F.G.S., in 1876.

It is highly probable that *Diplostylus Dawsoni*, Salter (1863), from the Coal Measures of Nova Scotia, was related to *Necroscilla Wilsoni*, but it does not appear to have possessed appendages to the penultimate body-segment as seen in the latter genus.

The remarkable genus *Pygocephalus*, represented by *P. Cooperi* and *P. Huxleyi*, from the Coal Measures of Shropshire, Lanarkshire, etc. offers characters common to the Stomatopoda, the Decapoda, and the Schizopoda, showing clearly the narrowness and artificiality of our classifications, which must ever need to be enlarged, in order to embrace all the varied forms which now live or have existed in past times.

Small, but well-preserved, specimens of Crustacea, belonging to the genus *Squilla*, described by Count Münster, in 1839, as *Sculda pennata*, are known from the Lithographic Stone of Solenhofen in Bavaria. They differ little (save in the spinose ornamentation on the abdominal and caudal segments and appendages) from the existing species of *Squilla*.

The Cretaceous deposits of Hakel, in the Lebanon, have yielded to the patient labours of the late Rev. Professor E. R. Lewis, F.G.S., of the Syrian Protestant College, Beirût, a well-preserved fossil *Squilla* which I described and named, in 1879, as *S. Lewisii*, after that enthusiastic geologist. A *Squilla* from the same locality (in 1886) has been named *Sculda syriaca* by Dames. Schlüter has named two species, *Pseudosculda lævis* and *Squilla cretacea*, from the Chalk of Westphalia.

Another fossil example met with was obtained from the London Clay of Highgate by the late Mr. N. T. Wetherell, F.G.S., and was described and figured by me, in 1879, as *Squilla Wetherelli*. Lovisato (1894) has recorded a *Squilla miocenica* from the Miocene of Sardinia. These Secondary and Tertiary *Squillæ* all closely approximate to existing forms of Stomatopoda, but the ancient Carboniferous representatives of this sub-order suggest a more generalized type of structure than those of later times.

Notwithstanding their wide distribution in time and space, the Squillidæ are of rare occurrence—both recent and fossil. Two causes may probably assist in explaining this: first, the thinness of the test, which would render it less likely to be preserved; and secondly, the fact that all the species are fossorial in their habits, forming

a very deep, nearly vertical, cylindrical burrow: this goes down for several feet into the sand, which is hardened by the pressure of the dorsal surface of the animal's body. They thus, too, often escape capture by collectors in the living state, and are too delicate to preserve well when fossil.

2. The SCHIZOPODA,—represented at the present day by *Mysis*, and numerous other allied genera,—occupy the most primitive position in the order Podophthalma, and still retain unchanged the original characters which distinguished the progenitors of the group in earlier times.

This is further emphasized by the fact that many Decapod Crustacea, in their more-advanced larval stages, pass through a '*Mysis*-stage' before reaching the adult condition.

Eight pairs of similarly-formed thoracic limbs are present (namely, three pairs of maxillipeds, and five pairs of posterior appendages), each being furnished with a well-developed exopodite and endopodite, and frequently bearing freely-projecting external gills, not covered by the cephalothoracic shield.

Considering the greater simplicity of the forms in this division, it seems highly probable that some of the earliest Macruran Crustacea, such, for instance, as the *Palæocrangon socialis* of Salter, from the Coal Measures of Fifeshire, may have belonged to the Schizopoda, but very few of these are sufficiently well-preserved to render exact determination possible.

Such forms as *Udorella Agassizi*, Oppel, from the Lithographic Slate of Kelheim, Bavaria, in which the cephalothoracic shield is short, and the legs uniform and provided with endopodite and exopodite, may, I think, with almost absolute certainty be referred to this division.

MACRURA.—The earliest example known of this modern division of Crustacea was obtained by Prof. R. P. Whitfield, in 1880, from the Erie Shales (Upper Devonian), Le Roy, Lake Co., Ohio, U.S.A., and named by him *Palæopalæmon Newberryi*, which in its general characters closely resembles the modern Crangonidea, the Shrimps and Prawns.

To this division must also be referred the *Palæocrangon eskdalensis* of Peach (1880), from the Lower Carboniferous rocks of Eskdale, Scotland.

Eight species of *Anthropalæmon* from the Coal Measures of Scotland and England; one from Illinois, U.S.A.; and one from

Nova Scotia, illustrate the abundance of these small crustacea in the Carboniferous period. They have many points in common, but probably deserve more than specific differentiation.

With the exception of *Anthrapalæmon Parkii*, *A. Traquairii*, and *A. Etheridgei*, which measure from 3 to 5 inches, the other species do not exceed 1 to 2 inches in length.

The carapace and body-segments were evidently and usually broadly expanded, as in the Eryonidæ; the large scale at the base of the outer antennæ suggests the Penæidæ; the strong basal joints of the inner pair of antennæ with bifid flagella, and the outer pair with single ones, are like many of the modern Caridea and Astacidea; the caudal appendages forcibly recall the rhipidina of the living Galatheidæ, in which, as in some ancient forms, there are two additional broad lamellæ to the tail-fan, developed one on either side of the telson. [This fact, as Peach correctly observes, strongly favours the view that the telson should not be treated as a mere median appendage, but as a true 21st body-segment.]

In the spinose ornamentation of the somites and caudal plates; in the broadening out of the segments of the abdomen and the short rounded form of the cephalothoracic shield (especially in *Anthrapalæmon Parkii*) one is reminded of the genus *Squilla*, but most probably this is only an analogy and nothing more. There is some evidence, though not quite satisfactory, that the branchiæ may have been partly exposed as in *Mysis*, but we need further light on this point.

Enough has been said, however, to show that the small Carboniferous Crustacea are much more generalized than their modern descendants, and probably stood in the position of great ancestors to most of the living Macrura and even to the Brachyura also.

The Caridea, embracing all the shrimps and prawns, and possibly also some of those ancient Carboniferous species of Anthrapalæmonidæ already referred to, are divisible into the Monocarpinea, the Polycarpinea, and the Crangonidea.

MONOCARPINEA.—In this section the fifth joint of the wrist of the second pair of thoracic limbs is not subdivided, and the chelæ of this pair are larger than those of the first pair.

The living representatives are divided into eleven families, the best known perhaps of which is that of the Palæmonidæ, embracing the true Prawns. In these the first and second pairs of thoracic

legs are chelate, the second being the longest pair; the carapace is even and rounded, with two points, the one above, the other beneath the peduncle of the external antennæ; the rostrum is of great length, curved upwards, and armed with 7 or 8 teeth above and 4 or 5 beneath; the inner antennæ have three filaments, two of which are long; the outer antennæ have filaments of very great length, and a long and pointed scale near the base. The oldest of this type known is the *Æger raiblana* from the Trias of Raibl, Austria. Two species of *Æger*, namely, *Æ. Marderi* and *Æ. Brodiei*, have been described by me from the Lower Lias of Lyme and of Warwickshire; five forms of the same genus have been figured by Münster and Oppel from Solenhofen, remarkable for the length of the rostrum and of their last pair of spinose pediform maxillipeds. The genera *Udora*, *Hefriga*, and *Elder*, from the Lithographic stone, probably all belong here.

Another Prawn, *Oplophorus van-der-Marchi*, Schlüter, is from the Chalk of Westphalia; two species of the genus *Homelys* (a freshwater Prawn) are from the Miocene of Oeningen; *Micropsalis papyracea*, H. v. Meyer, from the Tertiary Paper-coal of Rott, near Bonn, and *Palæmon exul*, Fritsch, from the Tertiary of Bohemia, complete this tribe.

POLYCARPINEA.—This section embraces the families Nikidæ, Alphæidæ, Hippolytidæ, and Pandalidæ. All the members of this group are distinguished by one common character: it is, that the second pair of slender thoracic legs have the carpus, or fifth joint, multiarticulate—that is, subdivided into a greater or less number of minor joints, like the flagellum of the lobster's antenna.

It is interesting to record that this remarkable and multiversatile hand had already been in use, no doubt prior to the Upper Jurassic period, for the genus *Blaculla* had just such slender limbs of this pattern, one fourth longer than its entire body. Three species have been noticed by Oppel from the Lithographic Stone of Solenhofen in Bavaria; while 27 genera of world-wide distribution still illustrate the convenience of this form of limb, which may serve to assist this small Shrimp to extract, from spiral shells and slender worm-tubes, food of a nutritious and appetizing kind.

CRANGONIDEA.—In *Crangon* the rostrum is absent or rudimentary; the inner antennæ have a dilated base terminating in two filaments; the external antennæ are nearly on the same line with the inner ones, and have a large scale at the base; the first pair of thoracic legs is subchelate; and the finger is inflected to meet a small

rudimentary thumb. The hinder margin of the carapace is overlapped at the sides by the first segment of the abdomen.

It seems probable that *Udorella Agassizi*, from the Lithographic Stone of Solenhofen, belongs here: the feet are monodactylous, but the outer antennæ each have two flagella, and the thoracic feet carry endopodites externally, which may be gills as in *Mysis*. *Pseudocrangon tenuicaudus*, from the Chalk of Westphalia, should, I think, be placed here.

The position of *Palæocrangon eskedalensis*, from the Lower Carboniferous of Scotland, is very doubtful.

*Mesocrangon atra* is from the Gault of Folkestone, and *Pseudocrangon* from the Chalk of the Lebanon.

The PENÆIDEA, typified by the genus *Penæus*, are a group abundantly represented in the Secondary rocks. The oldest form is probably the *Penæus liassicus*, Oppel, from the Lower Lias, Schambelen, Switzerland, and next comes *P. Sharpii*, H. Woodw., from the Upper Lias of Northampton. There are, moreover, five well-preserved species, figured and described by Oppel from the Lithographic Stone of Solenhofen. *Acanthochirus* 3 species, *Bylgia* 3 species, *Drobna* 2 species, and *Dusa* ? 3 species, are also considered to belong to the Penæidæ. *Penæus septemspinatus*, Dames, and *P. libanensis*, Brocchi, are from the Cretaceous of the Lebanon.

*Penæus* and 20 other genera allied to it are living at the present day very widely distributed geographically. The New South Wales species, *P. esculentus*, attains a length of 9 inches, and is largely used for food. The genus is of especial interest, not only as occurring fossil, or as being edible, but from the fact that, so far as we at present know, it is the only Macrurous Decapod in which the young passes from the egg as a simple *Nauplius*-larva, similar to that of a young Copepod, Cirripede, or Phyllopod-larva just hatched from the egg, and advances through a series of moults to a *Mysis*-formed zoea before attaining the adult stage.

ASTACIDEA.—Of the section Astacidea, the Eryontidæ occupy the first family, but they are peculiar and vary considerably from the ordinary type.

ERYONTIDÆ.—The genus *Eryon* was first made known by Desmarest in 1822, and was applied by him to a group of Macrurous Crustacea with a broad and flat carapace, strongly notched or indented around the anterior border, but with straight sides; the antennules are small, and bear multiarticulate flagella: there is a narrow scale near the base of each outer antenna, the flagellum being of moderate

length and stoutness. The abdominal segments are short and flat, but narrower than the carapace, and terminate in a rather pointed telson and 4 tail-laminæ. The first pair of thoracic legs are nearly as long as the body: all the limbs have chelate extremities, save the last pair, the extremities of which are simple.

It is not improbable that the earliest members of this ancient family (which attained its majority in the Upper Jurassic period) may be traced back as far as the Lower Carboniferous of Eskdale, Scotland; and they may be identified with such species as *Anthrapalæmon Macconochii*, *A. Woodwardii*, and some others (see Quart. Journ. Geol. Soc. 1879, vol. xxxv. pl. xxiii. p. 464) described by R. Etheridge, Jun. Another early form is the *Eryon raiblanus*, Bronn, sp., from the Trias of Raibl, Bohemia; followed by the *Eryon (Tropifer) lævis* of Gould from the Rhætic Bone-bed of Aust.

In the Lias formation there are ten described species, namely:—

*Eryon Calvadosii*, Morière, U. Lias, Caine, Calvados.

„ *Hartmanni*, Meyer, U. Lias, Würtemberg.

„ *Edwardsi*, Morière, U. Lias, Calvados.

„ *Moorei*, H. Woodw., U. Lias, Ilminster.

„ *Escheri*, Oppel, L. Lias, Baden.

„ *antiquus*, Brodp., L. Lias, Lyme Regis.

„ *barrovensis*, M'Coy, L. Lias, Barrow-on-Soar.

„ *wilmcotensis*, H. Woodw., L. Lias, Wilmcote.

„ *Brodiei*, H. Woodw., L. Lias, Lyme Regis.

„ *crassichelis*, H. Woodw., L. Lias, Lyme Regis.

One species occurs in the Great Oolite (Stonesfield Slate), namely, the *Eryon Stoddarti* of H. Woodward, while the *Eryon Perroni* of Étallon occurs in the Oxford Clay of Calmoutiers, Haute Saône, France.

Ten species of *Eryon* have been described from the Lithographic Stone of Solenhofen (probably near the horizon of the Kimmeridge Clay of England), namely:—

*Eryon propinquus*, Schloth.

„ *spinimanus*, Germar.

„ *orbiculatus*, Münst.

„ *elongatus*, Münst.

„ *arctiformis*, Schloth.

*Eryon bilobatus*, Münst.

„ *longipes*, Fraas.

„ *Schuberti*, Meyer.

„ *Redtenbacheri*, Münst.

„ *Oppeli*, H. Woodw.

I have described one Lower Cretaceous species under the name of *Eryon neocomiensis*, from the Neocomian of Silesia.

Lastly, we are indebted to the Naturalists of the *Challenger* Expedition for a knowledge of several living representatives of

the family Eryontidæ, referred to the genera *Polycheles*, *Pentacheles*, *Stereomastis*, and *Willemoesia*, from the Mediterranean, the Atlantic, and the Pacific, obtained from depths varying between 220 and 1900 fathoms. The recent species bear a very close resemblance to their Liassic and Oolitic ancestors, and they offer a striking illustration of the vast length of time over which a family may extend with very little alteration as regards general form.

What is the reason for the remarkable fact that so many old-world genera, belonging to such varied forms as *Nautilus*, *Pleurotomaria*, *Pholadomya*, *Arca*, *Calveria*, *Pentacrinus*, *Polycheles*, etc., dating from the Mesozoic period rather than the modern one, should still be found living in the deeper waters of our present oceans? Are we justified in concluding that they have so survived because those areas have remained undisturbed since the close of the Permian epoch? Or have they been compelled to occupy the deeper waters by other and stronger forms of marine life?

The SCYLLARIDEA might, at first sight, appear to offer an analogy, in their broadly-expanded and flattened-out cephalothorax and abdomen, to the genus *Eryon*, but they are in reality very widely separated from that family (which are Astacidea), the broad and serrated front of the carapace in *Scyllarus*, *Thenus*, and *Ibacus* being largely due to the very singular modification of the great pair of outer antennæ, the joints of which are flattened out into enormously broad and spinous fan-shaped scales, the eyes being usually inserted in deep hollows near their bases at the outer anterior angles of the head, but in *Ibacus* they are set nearer the front centre.

These singular forms are recorded as far back as the Gault, two species having been noticed by me from that formation and named *Scyllaridia Gardneri* and *Scyllaridia punctata* (Geol. Mag. 1873). *Ibacus præcursor* of Dames is from the Chalk Rock of the Lebanon. Other species from the London Clay have been figured and described as *Scyllaridia Koenigii*, *S. Bellii*, and *Thenops scyllariformis*, all from the Isle of Sheppey.

It is interesting to record that the late Prof. von Seebach discovered and described a larval Palinurid from the Lithographic stone of Solenhofen, well known—among living Crustacea—as ‘the Glass-crab,’ *Phyllosoma*<sup>1</sup>; some of these *Phyllosomæ* have been proved to be the larval stages of the Scyllaridæ.

<sup>1</sup> Münster, ‘Beiträge zur Petrefaktenkunde,’ Heft i. p. 84, pl. viii. figs. 3, 4. 4to. 1839.

Prof. Dames has described and figured two supposed larval forms of Crustacea from the Cretaceous of the Lebanon, under the names of *Pseuderichthus cretaceus* and *Protozoëa Hilgendorfi*, which, in the long produced fore-and-aft spines on the carapace, call to mind the larvæ of *Hippa*, *Porcellana*, and of some other living Decapoda.

**PALINURIDÆ.**—In *Palinurus* the carapace is less expanded and is longitudinally subcylindrical, with the orbits partially excavated and the eyes protected by strong spines; the external antennæ are very thick and long, their basal joints strong and spinous. The internal antennæ are principally composed of three long joints, with two small flagella at their extremities. All the feet are monodactylous. The tail is very broad, and the outer lamella is not jointed.

*Palinurina longipes*, Münster, is found in the three divisions of the Lias of England, and in the Lithographic stone of Solenhofen, Bavaria, and other localities.

*Palinurus (Glyphæa) Sæmanni*, Oppel, sp., and *P. Woodwardi*, Fritsch, come, the former from Solenhofen, and the latter from the Chalk of Bohemia. *P. nanodactylus*, Schl., sp., is from the Chalk of Sendenhorst, Westphalia.

*Cancrinus claviger* and *Cancrinus latipes* make us acquainted with a very remarkable Palinurid from Solenhofen, in which the outer antennæ are developed into large multiarticulate club-shaped organs.

Here is also placed a singular crustacean with simple monodactyle thoracic limbs, from the Lower Lias of Barrow-on-Soar, Leicestershire, named by me *Præatya scabrosa*.

*Archæocarabus Bowerbankii*, M'Coy, carries the Palinuridæ on into the Eocene Tertiary strata, and the *Palinurus vulgaris* (or common 'Spiny' Crawfish) is living around the rocky parts of our own coasts and those of France and the Mediterranean, and elsewhere, abundantly to-day.

There are several fossil forms of long-armed monodactylous crustaceans which have been placed here, presumably for convenience; beginning with *Scapheus ancylochelis*, H. Woodw., from the Lower Lias of Lyme Regis (Quart. Journ. Geol. Soc. vol. xix. 1863, pl. xv.); *Mecochirus Pearcei*, M'Coy, and *M. socialis*, Meyer, sp., from the Oxford Clay of Christian Malford, Wiltshire; *Mecochirus Peytoni*, H. Woodw., from the Kimmeridge Clay, 'Sub-Wealden Boring,' Sussex; and represented by six long-armed species from the Lithographic Stone of Solenhofen Bavaria. These singular forms were



probably all of them burrowing species, using their long arms to assist them in the process.

**GLYPHÆIDÆ.**—This family is represented by the genus *Pemphix*, and appears first in the Muschelkalk of Crailsheim, Germany. It approaches somewhat the modern *Palinurus* in character: Desmarest, who first described it, in 1822, placing it in that genus. It has a strongly-marked warty carapace, large outer antennæ, and the first pair of thoracic legs are monodactylous. A number of small carapaces referred to *Palæopemphix* by Prof. Gemmellaro, of Palermo, have been figured and described by him from the *Fusulina*-Limestone of Sicily as *P. sosiensis*, *P. affinis*, and *P. Meyeri*; but no appendages have been found with these carapaces.

Many forms, referred to the genera *Glyphæa* and *Pseudoglyphæa*, with the regions of the cephalothorax strongly accentuated, and having monodactylous thoracic feet, occur in the Jurassic rocks of this country and of Solenhofen, while species of *Glyphæa* and *Meyeria* occur in the Greensand and Chalk of England and Bohemia.

**ASTACIDEA.**—As several of the characters attributed to this tribe are certainly applicable to some, if not to all, the small forms referred to *Anthropalemon* in the Carboniferous Period, we are probably justified in considering this as the more generalized ancestor of all the Astacidea.

No fewer than 39 species of the genus *Eryma* occur from the Middle Lias to the Lithographic Stone (=Kimmeridgian), while *Astacus*, *Pseudastacus*, *Hoploparia*, *Enoploclytia*, *Palæastacus*, and other allied genera carry us through the Cretaceous and Tertiary series up to the recent *Nephrops* and *Homarus*, representing the marine branch, and to the Potamobiidæ and Parastacidæ, the former embracing all the freshwater forms of Crayfish in the Northern, and the latter all those in the Southern Hemisphere.

In the Jurassic we also have:—

*Eryma Villersii*, Oxfordian, Calvados.

In the Cretaceous we have also:—

*Pseudastacus hakelensis*, O. Fraas.

„ *minor*, O. Fraas.

*Nymphæops coesfeldiensis*, Schlüt., Chalk, Westphalia.

*Cambarus primævus*, Packard, Lower Tertiary, Wyoming.

*Astacus politus* of Schlüter, Chalk, Westphalia.

*Homarus Bosquetii*, Cretaceous, Maestricht.

„ *Percyi*, Rupelmonde, Brabant.

„ *Bredai*, Pels, Cretaceous, Maestricht.

The existence of this Astacomorphous type from Palæozoic times exactly corresponds with its remarkable and world-wide distribution at the present day. The late Prof. Huxley suggested that the descendants of *Eryma* in Jurassic times gave rise to *Enoploclytia* and *Hoploparia* in the Cretaceous period, and these to the modern marine Homarina: *per contra*—that *Pseudastacus*, in the Jurassic, originated the freshwater Potamobiidæ, which have, in the long period of time that has since elapsed, not only split up into the northern and southern potamobine and parastacine types, but have become distributed from land to land by overland and freshwater lines of communication, since broken up and removed, but which must, upon this hypothesis of descent, have formerly existed; unless we are prepared to adopt the theory of geographical distribution of animals, propounded by St. Augustine for insular floras and faunas—namely, that they were carried there by angels.

The magnitude of the problem of the Astacidea becomes more apparent when we bear in mind that these freshwater Crayfishes are distributed over the rivers and lakes of 12 widely separated and extensive land-areas (each being marked by its own geographical species), such as the European-Asiatic area, the Amurland, the Japanese, the West North American and the East North American, the Brazilian, the Chilian, the New Zealand, the Fijian, the Tasmanian, the Australian, the Madagascar areas.

It is not without interest to observe the strong cousinly resemblance between many of these forms now separated so far by time and space. Take, for instance, two of the largest living forms—the *Astacoides madagascariensis*, from Madagascar, and the *Astacoides armatus*, from the Murray River, South Australia; they closely resemble one another in form and in general structure, although now separated by the breadth of the great Indian Ocean; but the former species is smooth, or only slightly scabrous, while the latter, as its name suggests, is armed with prickly spines on the sides of the cephalothorax and the abdominal somites.

This spinose ornamentation may seem trivial, but it is, I believe, unique of its kind among living Astacides. Strange to say, it finds its homologue not in another living or fossil form of Crayfish, but in an ancestor of the marine branch of the Astacidea, the *Enoploclytia sussexiensis* from the Chalk of England.

The THALASSINIDEA form a remarkable family of true fossorial Macrura, having a long and slender abdomen, the segments of which do not overlap, and the epimera are feebly developed; they have also

a small carapace, compressed on the sides; the eye-stalks are small; both pairs of antennæ have long peduncles. The first pair of legs are imperfectly chelate and expanded for digging at their extremities, the others are shorter and hirsute. The swimming-plates of the tail are slender and pointed.

The Thalassinæ are common on the west coast of Australia and in the Fiji Islands, and always inhabit deep burrows, which they excavate in the sand or mud near low water. One fossil species, *Th. Emeryi* (Bell), has been described by Prof. Bell from Western Australia, where *Th. scorpioides* is found living.

The genus *Callianassa* (belonging to the same family) occurs on the coasts of Ireland, Britain, France, and the Mediterranean, the shores of North America, and elsewhere. The carapace is small, without a rostrum; the abdomen large; the integument is not very firm. The front legs are large and strong, one hand being very much more developed than the other; the third pair of legs are wide near the end, and are used by the animal in digging.

This lobster lives habitually concealed in its burrow with only its strong chelate fore-limbs projecting, ready to seize on any passing prey. As a result of this habit, perfect specimens are seldom to be obtained, but the great claws are frequently to be seen, both recent and fossil, in Museums.

A species of the genus *Callianassa* is met with in the Kimmeridge Clay; one species occurs in the Cretaceous of North America, ten in that of Europe, and one in the Eocene of the Isle of Wight. So far as one is able to rely upon the imperfectly preserved fossil remains, it would appear that the species of this genus have undergone but little change, and occupy to-day the coasts of relatively the same areas in which their fossil remains have been found as far back as the Upper Jurassic.

*Upogebia* (= *Gebia*) is an equally active burrowing form, and closely related to *Callianassa*, from our own shores and those of North America. Passing over the Axiidæ, also closely related, we come to the Thaumastocheilidæ, established for the genus *Thaumastocheles*, a very remarkable burrowing form dredged from 450 fathoms and more, off St. Thomas, in the West Indies, by the *Challenger* Expedition. It is very like the Callianassidæ in general appearance, but one of the hands is modified into a very strong claw, armed with a long, slender, and delicate forceps-like chela provided with slender and very numerous teeth. This curious burrowing form of Crustacean (*Thaumastocheles Zaleucus*), living now in deep water

off the West Indies, is represented by two almost identical forms, described by Prof. Dr. Anton Fritsch, namely, *Stenocheltes esocinus*, Fr., and *Stenocheltes parvulus*, Fr., both from the Chalk of Bohemia. *Ischnodactylus inæquidens*, Pelseneer, from the Uppermost Chalk of Limburg, belongs apparently to the same group of Crustacea.

Is *Thaumastocheles Zaleucus* a deep-water survival from the Chalk-sea of Europe, and did its area extend to the West Indies?

Dr. Paul Pelseneer has figured and described a cephalothorax of *Galathea* (named *G. Ubaghsi*) from the Maestrichtien or Upper Chalk of Limburg, and I have received from Miss Caroline Birley another example of the same genus from the Danien Upper Chalk of Faxe.

BRACHYURA (*Crabs*).—Standing between the long-tailed Lobsters (*Macrura*) and the short-tailed Crabs (*Brachyura*) is an anomalous group of forms, of considerable extent among living Podophthalma, fortunately, but few of which are met with as fossils. These were formerly elevated into the rank of a distinct tribe, the 'Anomura,' but a careful consideration soon reveals the fact that this name, like some still in use in other zoological groups, is but the confession of our ignorance as to the exact position of the individuals relegated to such scientific dust-bins.

G. O. Sars has made an earnest effort to clear up the relations of some of these Anomura, and, from a study of their larval stages, he is led to refer to the *Macrura* the following forms, namely:—*Lithodes*, *Eupagurus*, *Anapagurus*, *Munidopsis*, *Galathea*, *Munida*, and *Porcellana*. Of these, *Porcellana* and *Lithodes* heretofore had been placed on the side of the *Brachyura*, but, tested by their larval stages, they are really *Macrura*. On the other hand, the *Dromidæ*, *Homolidæ*, *Raninidæ*, and *Dorippidæ* belong to the anomalous forms of *Brachyura*. Such 'borderland' genera are among the familiar difficulties known to every zoologist in the study of any natural order, even when fossil forms are not, as in the present instance, taken into consideration.

In this anomalous group we are frequently enabled to penetrate the veil which Nature too often spreads over her workings, and to discover the secret of the transformation in appearance which many of these adult crustacea assume, and detect how it has been brought about.

Thus we find that all those forms which constantly hide themselves in burrows, or in shells of dead mollusks, living sponges, sea-anemones, and other like hiding-places, become in time quite

warped and distorted from their natural shape, by their mode of life, and lose the use of certain members, which cease to grow, while others develop peculiarities in structure, or they may, as in the Soldier-crabs, lose the hard coverings to their bodies. ‘*Dromia* does not carry about with it a turbinated shell, like *Pagurus*, but clothes itself in the bright skin of its victim, a sea-lemon (*Doris*), for example, or encourages a parasitic sponge of showy colour to grow upon its back, holding it in its place with its two hind pairs of rudimentary feet, just as the other true hermit-crabs hold their shells on over their soft-skinned bodies’ (Gosse).

Species of *Dorippe* from Singapore have been observed by Dr. Archer, carrying the leaf of a mangrove-tree over their backs, or the half of a dead bivalve shell, to conceal them from view.

Specimens of *Hyas* not only dress themselves in living seaweeds, which they deliberately plant upon their backs, but if their surroundings be changed they will remove these, and replace them with some others more suitable in colour—to match with their new conditions.

In those forms which, like *Hippa*, *Ranina*, *Zanclifer*, and others, are expert diggers, the body and legs are both specially modified; enabling the animal to sink down rapidly backward into the wet sand, or soft mud, and so escape from capture.

FOSSIL FORMS.—Of some of the oldest forms referred to this division there is considerable doubt, owing to want of more complete fossil evidence.

Thus, it is not easy to determine the true nature of the genus *Oonocarcinus*, of which Prof. Gemmellaro has figured and described three species from the *Fusulina*-Limestone of Palermo, Sicily.

With these doubtful forms is associated another, named *Paraprosopon Reussii*, Gemm., which is certainly referable to the genus *Cyclus*.

It is possible that *Oonocarcinus* may be part of an Arachnid, a supposition which its ornament suggests. This is certainly the case with regard to a supposed Brachyurous Crustacean, described by me, in 1878, under the name of *Brachypyge carbonis*, from the Coal Measures of Mons, Belgium. It proves to be almost certainly the abdomen, not of a Crab, but of an Arachnid near to *Eophrynus Prestvici*, H. Woodw., from the Coal Measures of Dudley (Geol. Mag. 1871, p. 385).

In 1866 I had the pleasure of describing a short-tailed crab,

from the Forest Marble of Malmesbury, Wiltshire, under the name of *Palæinachus longipes* (Quart. Journ. Geol. Soc. vol. xxii. 1866, pp. 493-4, pl. xxiv. fig. 1), which is still the oldest fossil crab known.

As the limbs are preserved, as well as the carapace, its determination is all the more satisfactory and reliable. The legs are extremely long and slender; in this respect, and also in their form and in that of the carapace, with its remarkable prominent tubercles in front, it closely resembles the common 'Spider-Crabs'—the *Maidæ* and *Leptopodidæ*—living on our own coasts at the present day, and the great Japanese Crab, *Mecocheirus Kempferi*, of De Haan. In 1868, I figured and described the carapace of another Brachyuran Crustacean, but without limbs attached, from the Great Oolite of Stonesfield, under the name of *Prosopon mammillatum*. The Upper White Jura of Ulm, Germany, has yielded carapaces of several minute crustacea, which are either Brachyurous or Anomurous; these are generally placed under the Dromiacea, but unfortunately no limbs or abdominal segments have been found associated with them. As many as 3 genera and 26 species of these forms have been figured and described by H. von Meyer, Quenstedt, and Reuss.

Although short-tailed or Anomalous Crabs are rare in the Jurassic Series, they become more abundant in Cretaceous times, and we find not only the earliest and simplest forms, such as Dromiacea, but also representatives of all the great families of the Brachyura.

Commencing with the DROMIACEA, we find a genus, like *Dromilites*, which I have named *Prosopon Etheridgei*, occurring in the Cretaceous of Queensland, Australia; *Cyphonotus incertus* and *Plagiophthalmus oviformis*, from the Greensand of Cambridge and of Wiltshire; *Diaulax Carteriana*, from the Cambridge Greensand, and *D. feliceps*, from the Gault, Folkestone; *Platypodia Oweni*, from the Chalk of Sussex; *Polycnemidium pustulosum*, from the Chalk of Bohemia; *Glyphithyreus formosus*, from the Pläner-Kalk of Ebendorf; *Dromiopsis rugosa*, from the Chalk of Faxoe; and *Homolopsis Edwardsi*, from the Gault and Greensand of England.

*Dromilites Lamareckii*, of Desmarest, and *Goniochele angulata*, of Bell, are both London Clay forms from the Isle of Sheppey; *Stenodromia* is from the Eocene, Biarritz. These complete the Tertiary record, while about 9 genera and numerous species are widely distributed over the seas of the world and are still living.

In the RANININEA we have *Raninella elongata* and *R. Mülleri*, from the Cretaceous of Aachen; *Raninoides lævis*, from the Chalk of Osnabrück; and *Ranina cretacea*, Dames, from the Lebanon. From the Eocene we have *Notopus Beyrichii*, Bittner, and *Palæonotopus Barroisii*, Brocchi, from the Paris Basin; *Ranina Marestiana*, König, *R. speciosa*, Münst., and *R. bavarica*, Ebert, from the Eocene, Kressenberg, Bavaria, and *R. Bouilleana*, Milne-Edw., from the Eocene, Biarritz; *Ranina Adamsii*, H. Woodw., from the Miocene of Malta; *R. palmea*, U. Tertiary, Asti, Piedmont; *R. speciosa*, Tertiary, Bünde; *R. oblonga*, from Ebenda; whilst *Ranina scabra* (vel *dentata*), from Amboina, *Raninoides personatus*, *Notopoides latus*, *Notopus dorsipes*, *Lyreidus tridentatus*, *L. Bairdii*, and *Zanclicher caribensis*, live at the present day on various subtropical coasts.

This concludes all that I have to say regarding the Anomalous Brachyura.

In the OXYSTOMATA, or 'sharp-mouthed' crabs, which derive their tribal name from the more or less triangular shape of the buccal region, the carapace is convex, with the antero-lateral margins arcuate, orbiculate, subglobose or more or less oblong—in fact variable in form. These are represented among living forms by the Dorippidæ, the Calappidæ, the Matutidæ, and the Leucosidæ.

The DORIPPIDÆ are certainly anomalous forms although placed in this division, and would seem more suitably located with the preceding group. The carapace is very broad behind, with projecting abdominal somites as in *Dromia*—the last two (4th and 5th) pairs of legs being short and feeble with strongly hooked extremities, and carried rather on the dorsal surface—the chelipeds are small, while the 2nd and 3rd pairs of ambulatory legs are long and adapted for running. The weak and small 4th and 5th legs are probably used to carry foreign objects on the back for the purpose of concealment, as noticed by Surgeon-Major Archer at Singapore.

In the CALAPPIDÆ the carapace is narrow but deep in front, and expanded behind into thin, broad, shield-like expansions which cover and conceal the bases of the walking-legs. The chelate fore-limbs are very flat and strongly crested, like a cock's-comb, and when pressed close to the carapace they meet in front and form an efficient shield to the body.

In the MATUTIDÆ, represented by *Matuta victor*, the 3rd, 4th, and 5th pairs of limbs are suitable either as paddles or for burrowing in the wet sand, in which they are very expert.

The LEUCOSIADÆ are small, well-marked crabs, with rather long chelipeds and a rounded helmet-like carapace, sometimes polished or covered with minute tubercles, the small eyes being inserted deeply and near together on the front of the blunt projecting rostrum: 3 or 4 joints of the abdomen in the female are coalesced into a broadly rounded convex plate, on the inner concave side of which the eggs are carried and concealed.

The Oxystomata form the first division of the true Brachyura represented in the Cretaceous formation by at least 9 genera, commencing with *Necrocarcinus senonensis*, Schl., *N. Woodwardii*, Chalk, Westphalia, and *N. tricarinatus*, H. Woodw., from the Greensand; followed by *N. avicularis*, Fr., and *N. perlatus*, Fr., from the Chalk of Bohemia: thence we pass on to *Orithopsis Bonneyi*, Carter, Greensand; and to *Orithya Bechei* from the Gault, Folkestone, and *O. Woodwardi* from the Chalk Marl, Isle of Wight. *Trachynotus sulcatus*, Greensand, Wiltshire, and *Mithracites vectensis*, Isle of Wight, with *Hemioon Cunningtoni*, Greensand, Wiltshire and Cambridge, leading on to *Eucorystes Carteri*, Greensand, Cambridge, *Palæocorystes Broderipii* and *P. Stokesii*, Greensand and Gault, Folkestone. *P. lævis* is from Westphalia; *P. Callianassarum* and *P. isericus* come from the Chalk of Bohemia; *P. Normanii*, Bell, from the Chalk Marl, Isle of Wight; *P. Harveyi*, H. Woodw., from the Cretaceous of Vancouver Island, and *P. Mülleri* from the Chalk of Maestricht.

Passing upward into the Eocene Tertiary we have *P. glabra*, Eocene, Portsmouth, and *Cyclocorystes pulchellus*, Bell, London Clay, Holloway; *Mithracia libinioides*, Bell, and *Campylostoma matutiformis*, Bell, from the London Clay, Sheppey; *Hepaticus pulchellus*, Bittner, Eocene, Northern Italy, and Egypt; *Calappilia verrucosa*, Eocene, Biarritz, and *Calappa*, sp., Eocene, Hungary; *Typilobus*, sp., Eocene, East Indies, and *Matuta*, sp., Eocene, Hungary.

In the Miocene and Newer Tertiaries we meet with *Atelecyclus*, Miocene and Recent; *A. rugosus*, Miocene, Montpellier; *Palæomyra bispinosa*, Miocene, Turin; *Calappa*, sp., Newer Tertiary and Recent. *Ebalia Bryerii*, Leach, Suffolk Crag and Recent; *Leucosia subrhomboidalis* and *L. cranium*, Newer Tertiaries and Recent; also *Ixa tuberculata*, post-Tertiary, East Indies. *Corystes Cassivelaunus*, the Masked Crab, is a recent example of the same family.

In the OXYRHYNCHA, or 'sharp-snouted' crabs, represented by *Inachus*, *Maia*, *Hyas*, *Stenorhynchus*, etc., the carapace is narrow anteriorly and is usually provided with a pointed and bifid rostrum, the hepatic regions of the carapace being small and the branchial



regions large. The epistome is generally large, and the buccal region quadrate, with a straight anterior margin.

In long-bodied Crustacea the nervous system is divided into two parallel chords, with separate ganglia for each segment. In the Spider-Crabs the nervous system attains a high degree of concentration, there being only a thoracic and a cephalic ganglion, instead of about 15 separate centres, as in *Homarus*. Notwithstanding this high degree of cephalization, they do not display any great activity, but are generally of sluggish and slow-moving habits, their intelligence being principally directed to the arts of disguise and concealment in which they certainly display much ingenuity, especially in planting their backs and legs with seaweeds, corallines, *Alcyonia*, and the like, which they have been observed to change, from time to time, the better to suit the colours of their altered habitats.

This is undoubtedly one of the oldest tribes represented in geological time, being met with as far back as the Forest Marble (Great Oolite) of Wiltshire, and it disputes with the Dromiacea the ancestorship of all the short-tailed Podophthalma.

As before remarked, the earliest known crab is the *Palæinachus longipes*, H. Woodw., Forest Marble, Great Oolite, Malmesbury, Wiltshire. This is followed by *Lissiopsis transiens*, Fr., from the Chalk of Bohemia.

*Lambrus nummuliticus*, *Periacanthus horridus*, and *Micromaja tuberculata*, of Bittner, are all from the Eocene of Vicentino and other districts of Northern Italy.

*Micromithrax holsatica*, from the Miocene of Holstein, a species of *Maija* from the Miocene of Malta and another from the Coralline Crag of Suffolk, complete the list of the sharp-nosed crabs.

CYCLOMETOPA.—The crabs which are placed in the tribe of the Cyclometopa have the carapace arched in front and often broader than long; more rarely it is quadrate, or suborbicular, but in none of the members of this division is the carapace rostrate. It includes the Cancridea, Cyclinea, and Thelphusinea. [The Corystinea I would prefer to place with the Oxystomata.] Here is located that most ancient and astronomical genus—*Cancer*, with *Xantho*, *Ozius*, *Trapezia*, *Carcinus*, *Portunus*, *Polybius*, *Podophthalmus*, *Thelphusa*, and many more well-known forms, several being largely eaten by mankind. Members of the Portunidæ occur in the Eocene, and of the Cancridæ as far back as Cretaceous times.

The Cyclometopa (circular-fronted crabs) of the division CAN-

CRIDÆ make their first appearance in the Cretaceous Series, with *Xantho Fischeri* from the Gault of Neuchâtel, and *Colaxanthus formosus* from the Upper Greensand (Cenomanian) of Le Mans, Sarthe.

Next we find *Xanthosia* (with 2 species) in the Upper Greensand of Wiltshire and Cambridge; *Etyus* (with 3 species from the same locality as *Xanthosia*, and one species from the Pläner-Kalk of Bohemia); *Plagiolophus formosus* from the Upper Cretaceous of Mecklenburg, and *Cancer* (with one species from Mecklenburg and 3 from the Chalk of Bohemia); *Xanthopsis minor*, Stolley, Middle Oligocene, Southern and Northern Germany. *Xanthopsis Dufourii*, A. Milne-Edw., Eocene; *Plagiolophus Wetherellii*, Bell, *Xanthilites* (1 species), *Necrozium Bowerbankii*, A. Milne-Edw., *Xanthopsis* (with 4 species)—all from the London Clay of Sheppey; also 5 species of *Xanthopsis* and 1 of *Xanthelites* from the Nummulitic of Bavaria, of France, and Germany. *Etisus*, sp., is from the Nummulitic of the Landes, France.

*Palæocarpilius* has 6 species, found in the Eocene of Kressenberg, the Nummulitic of Verona, of Dax and the Gironde, and the Calcaire Grossier near Paris. *Harpactocarcinus* has 8 species from the Nummulitic of Italy, France, Spain, and New Zealand; and the genus *Neptunus*, with 8 species, comes from the Nummulitic of the Vicentino, of Sassari, and Montpellier, from the Miocene of Kutch, India, and from Malta.

*Podophthalmus* has only a single species, from the Tertiary; and *Syphax crassus* is known from the Nummulitic of Aude, France.

Eight species of *Cancer* occur in the Eocene of France, and in the Miocene and Pliocene of Italy, etc.

*Phlyctenodes*, with 2 species, is found in the Nummulitic of France, and one species in the Miocene of the Vicentino.

*Eriphia spinifrons* is from the Quaternary of Nice; *Galena obscura* from China; *Lobonotus sculptus* is known from San Domingo; *Palæocarpilius*, with 2 species, occurs in the Miocene of Kutch, India.

*Atergatis*, sp., has been obtained from the Miocene of Malta and *A. dubius* from that of Dax, Southern France.

A crab which delights in a very remarkable serrated front to his carapace and also enjoys the longest name extant—*Lobocarcinus Paulino-Wurtembergensis*—occurs very abundantly in the Miocene beds of the Mokattam quarries near Cairo, Egypt.

*Actæa persica* is met with in the Newer Tertiary of the Isle of Kharu, near Bushire, Persian Gulf.

*Zozymus Desmaresti* is found in the Quaternary of Eastern Asia

Those of the section *PORTUNIDÆ* met with in a fossil state comprise :—*Carcinus peruviansis* from the Cretaceous, Peru, and *C. mænas*, subfossil, Jarrow Docks, Newcastle-on-Tyne ; *Portunites incerta*, Bell, London Clay, Sheppey, and *Portunites*, sp., Miocene, Malta ; *Titanocarcinus serratifrons*, from the Cretaceous, Ciply, Belgium ; and five other species from the Nummulitic and Miocene of Italy and France ; *Cyamocarcinus angustifrons*, Bittner, Eocene, Schio ; *Goniosoma antiqua*, Milne-Edw., Nummulitic Limestone, Salcedon, Northern Italy, and *Menippe Chauvinii*, Upper Eocene, Noyon, France. *Scylla Michelinii* from the Miocene of Anjou, and *S. serrata*, Miocene, Malta, Quaternary, Philippines, and also living in the seas of the East Indies. *Goniosoma antiqua* and *Achelous obtusus* are from the Upper Eocene of the Vicentino. *Enoplonotus armatus* comes from the Miocene of Monte Bolca, and *Psammodarcinus Hericartii* is from the Lower Eocene of Meaux, France. *Rhachisoma bispinosa* and *R. echinata* (H. Woodw.) are from the Lower Eocene of Portsmouth.

The *CATOMETOPA* have the front of the carapace bent downwards and broader in front, often subquadrate, but not rostrate. The epistome is short, often almost linear. Here are placed the Gecarcinidæ, the Ocypodidæ, the Grapsidæ, and the Pinnotheridæ. It is in this tribe that we meet with some of the most active and vigilant running forms of Crustacea—the ‘Land-crabs,’ which inhabit the warmer regions of the earth north and south of the Equator, and are able to respire moist air with their gills on land, as effectively as *Cancer*, *Polybius*, and others, breathe aerated water in the sea.

The swift-footed Sand-crabs (*Ocypoda*) are exclusively terrestrial animals, and can scarcely live for a single day in water ; in a much shorter period, indeed, if kept in the water, a state of complete relaxation occurs, and all voluntary movements cease. Members of this tribe are met with as far back as the Cretaceous period.

In the *Catometopa* (represented by that interesting, active, and highly intelligent tribe the existing Land-crabs and Shore-crabs of subtropical regions) the fossil forms are not nearly so numerous as in the last division.

Commencing with *Podopilumnus Fittoni* from the Greensand of Lyme Regis, Dorset, and *Lithophylax* in the Chalk, we meet with *Litoricola glabra*, H. Woodw., and *L. dentata* in the Lower Eocene of Portsmouth (see Quart. Journ. Geol. Soc. vol. xxix. 1873, pl. ii.) ; *Edisoma ambiguum*, in the London Clay of Sheppey ; and an undoubted Land-crab, *Goniocypoda Edwardsii*, H. Woodw., from

the Eocene of High Cliff, Hants. A *Palæograpsus*, sp., is known from the Eocene of Northern Italy. *Colpocaris bullata* comes from the Nummulitic of Switzerland, *Cœloma vigil* from Vicenza, and *C. taunicum* from the Oligocene of Germany; *Cœloma rupeliense*, Stainier, from the Argile Rupelienne; *C. holsaticum*, Stolley, from Holstein. *Galenopsis crassifrons*, *G. Gervilleanus*, *G. pustulosus*, are all from the Nummulitic of Italy and France; and *G. Murchisoni* is from the Miocene of Sind, India. *Mioplax*, sp., is from the Miocene of Radoboj, Austria. *Telphusa speciosa*, *T. Quenstedtii*, and *Gecarcinus punctatus* are from the Miocene of Eningen; *Glyptonotus trispinosus*, *Macrophthalmus Latreillei*, *M. emarginata*, *M. incisa*, and a species of *Gelasimus* are from the Island of Hainan, where they occur in the Quaternary deposits, and are collected largely for medicine by the Chinese druggists, in whose pharmacopœia they form an important item as an antacid and for the cure of sores.

In this group of Land-crabs we have two genera and species in the Cretaceous, ten genera and eleven species in the Eocene and Oligocene, and eight genera and nine species in Miocene and Newer Tertiary strata.

Last year I invited your attention mainly to the state of our knowledge of the earlier and simpler forms of Crustacea inhabiting the Palæozoic seas, and placed in the great division of the ENTOMOSTRACA. I referred to the extinct Trilobita and the important advance in our knowledge of this group which we owe to American palæontologists. I spoke of the MEROSTOMATA, including therein the Eurypterida and Xiphosura—the former aquatic division being now entirely extinct, but having, no doubt, given origin, in its remote ancestry, to the terrestrial and air-breathing Scorpionida, which have come down from the Silurian epoch to our time, apparently but little changed in structure—while the latter (the living *Xiphosura*, ‘King-crabs’) have even adhered, in both their general form and their aquatic mode of respiration and life, to their Palæozoic progenitors.

I discussed the Palæozoic ‘giant Pod-shrimps,’ Phyllocarida, placed heretofore with the general group of the Phyllopoda—now claimed as the direct ancestors of the modern Malacostraca—but still represented by one living form, apparently but little changed,—the genus *Nebalia*.

Of the other divisions of the Branchiopoda I said but little, nor

could I do justice to the Ostracoda and Copepoda, while as regards the Cirripedia, on which Charles Darwin laboured so long and exhaustively, I have been silent, because I found the whole subject of the Crustacea too large for the time at my disposal.

To-day I have attempted, in a very imperfect manner, to bring into the focus of my discourse a summary of the fossil Malacostraca, to which our modern Crustacea chiefly belong. It is true that the evidences of the existence of this division prior to the Mesozoic epoch are but few and scanty; nevertheless, even in Carboniferous times, if not in still earlier eons, we catch a gleam of the light of the living life-forms of to-day, shining clearly, though afar off, down the corridors of time, revealing ancestral forms, the prototypes of those which people so abundantly our modern seas, proving that the living present and the far-distant past are indissolubly linked together, and that the stream of life has flowed, from its parent source, through all time, at first in tiny rills and murmuring streamlets, yet ever growing stronger, 'from running brooks to rivers wide,' pressing ever and for ever, onward, from the river to the sea.

As to the minute details of the course which the evolution of Crustacean life has followed in past times, we can, in many cases, only infer, we cannot absolutely prove our proposition.

Thus we have no doubt that the aquatic Eurypterida gave rise to the terrestrial Scorpionida, but we cannot show any direct evidence, because we have *Eurypterus* and *Scorpio* side by side in Upper Silurian rocks, but the earlier evolutionary history is still wanting.

Again, *Nebalia*-like forms are most probably in the direct line of the ancestry of the modern Malacostraca, and in the Carboniferous period we have *Cumacea*-like forms, which have doubtless been derived from *Ceratiocaris* and have given rise to higher Malacostraca; but Macruran and other forms of Podophthalma and Edriophthalma were already in existence in the Devonian, and both Cumaceæ and Nebaliæ continue to exist unchanged at the present day.

Looked at broadly, however, the Crustacea show the same upward and onward development which marks other living forms whose history can be traced. The great extinct orders of Eurypterida and Trilobita have disappeared—the other Entomostracan orders have survived, but they no longer occupy the whole field: with the close of Palæozoic times the Malacostraca have developed in strength, and

now occupy the stage associated with the Tracheata proper, and the King-crabs and Scorpions, which latter, like the Ostracoda and Phyllopoda, are survivals from a pre-Silurian age.

Truly—

‘The old order changeth, yielding place to new.’

My task is ended, and it now only remains my duty to efface myself officially, but before doing so I should like to express to the Council and Officers, and to the Fellows generally, my grateful sense of the honour which they conferred upon me when they placed me in this chair, and for the generous support and friendly forbearance which they have extended towards me in the performance of my duties. In this matter I cannot fail to recall how greatly I am indebted to the Secretaries and Treasurer, for the valuable assistance and advice which I have at all times received from them and from the permanent staff of the Society, without whose aid I could never have carried on the work devolving upon me.

In resigning the Presidential chair to my esteemed friend and successor, Dr. Henry Hicks, F.R.S., I feel that he is neither a stranger among us, nor inexperienced, for he has served as your Secretary for three years (1890–91–92), and has moreover had many years’ experience on the Council of this Society.

May he thoroughly enjoy, as I have done, the two chief pleasures of office—that of taking the chair and that of resigning it. Farewell.

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February 26th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

William Griffith, Esq., Waterloo Hotel, Aberystwith, South Wales; Joseph Colin Francis Johnson, Esq., J.P., Adelaide, and Constitutional Club, London; Peter MacLaren, Esq., 352 St. Vincent Street, Glasgow; and Edwin Perkins Ridley, Esq., 6 Paget Road, Ipswich, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On the Structure of the Plesiosaurian Skull.' By Charles W. Andrews, Esq., B.Sc., F.G.S.

2. 'On certain Granophyres, modified by the Incorporation of Gabbro Fragments, in Strath (Skye).' By Alfred Harker, Esq., M.A., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

3. 'Observations on the Geology of the Nile Valley, and on the Evidence of the greater Volume of that River at a former Period.' By Prof. E. Hull, M.A., LL.D., F.R.S., F.G.S.

4. 'The Fauna of the Keisley Limestone.—Part I.' By F. R. Cowper Reed, Esq., M.A., F.G.S.

The following specimens, maps, and photographs were exhibited :—

Cast of Skull of *Plesiosaurus macrocephalus*, Buckland, exhibited by C. W. Andrews, Esq., B.Sc., F.G.S., in illustration of his paper.

Specimens of Granophyres from Strath (Skye), exhibited by Alfred Harker, Esq., M.A., F.G.S., in illustration of his paper.

Fossils from the Keisley Limestone of Westmoreland, exhibited by F. R. Cowper Reed, Esq., M.A., F.G.S., in illustration of his paper.

Human Skull, found about 6 feet beneath the surface, not far from the banks of the Wye, somewhat below the city of Hereford, exhibited by the Rev. J. O. Bevan, F.G.S.

Geological Survey of England and Wales, New Series, 1-inch Map (Solid and Drift) Sheet 249, Newport (Mon.), by A. Strahan and W. Gibson, 1895, presented by the Director-General of H.M. Geological Survey.

Photographs of Stratified Volcanic Ash at Tantallon Castle, and of Boulders from the Bagshot District, etc., exhibited by Horace W. Monckton, Esq., F.L.S., F.G.S.

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March 11th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

George C. Bond, Esq., Aspley House, Nottingham; Sydney Fawns, Esq., F.C.S., 16 Onslow Gardens, S.W.; and Dr. J. Shearson Hyland, 3 Copthall Buildings, E.C., were elected Fellows of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced that, in connexion with the Hungarian Millennial Exhibition, a Congress of Mining and Geology would be held at Budapest on September 25th and 26th, 1896.

The following communications were read:—

1. 'On an Alpine Nickel-bearing Serpentine with Fulgurites.' By Miss E. Aston, B.Sc. With Petrographical Notes by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

2. 'The Pliocene Glaciation, Pre-Glacial Valleys, and Lake Basins of Subalpine Switzerland; with a Note on the Microscopic Structure of Tavayanaz Diabasic Tufa.' By C. S. Du Riche Preller, M.A., Ph.D., F.G.S., F.C.S., A.I.M.I.E., M.I.E.E.

3. 'Notes concerning certain Linear Marks in a Sedimentary Rock.' By Prof. J. E. Talmage, D.Sc., F.G.S.

The following specimens, photographs, and maps were exhibited:—

Specimens and microscope-sections of Alpine Nickel-bearing Serpentine with Fulgurites, exhibited by Prof. T. G. Bonney, D.Sc., F.R.S., V.P.G.S., in illustration of the paper by Miss E. Aston and himself.

Specimens, photographs, and microscope-section, exhibited by C. S. Du Riche Preller, M.A., Ph.D., F.G.S., in illustration of his paper.

Specimens and photographs of Linear Marks in an Argillaceous Sandstone, exhibited by Prof. J. E. Talmage, D.Sc., F.G.S., in illustration of his paper.

Fossils from the Marine Permian of the Salt Range, India, exhibited by F. G. Brook-Fox, Esq., F.G.S.

And the following maps presented by the Austro-Hungarian Geological Survey:—Geologische Spezialkarte der Umgebung von Wien, von Dionys Stur (in 6 sheets, scale  $\frac{1}{75,000}$ ); Geologische Karte der östlichen Ausläufer der Karnischen und Julischen Alpen, von Friedrich Teller (in 4 sheets, scale  $\frac{1}{75,000}$ ); and Geologische Karte von Olmütz, von Emil Tietze (scale  $\frac{1}{75,000}$ ).



March 25th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

Thomas Wilberforce Davies, Esq., 3 Burns Avenue, Liscard, Cheshire, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On Submerged Land-surfaces at Barry, Glamorganshire.' By A. Strahan, Esq., M.A., F.G.S. With Notes on the Fauna and Flora by Clement Reid, Esq., F.L.S., F.G.S., and an Appendix on the Microzoa by Prof. T. Rupert Jones, F.R.S., F.G.S., and F. Chapman, Esq., A.L.S., F.R.M.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

2. 'On a Phosphatic Chalk with *Holaster planus* at Lewes.' By A. Strahan, Esq., M.A., F.G.S. With an Appendix on the Ostracoda and Foraminifera by F. Chapman, Esq., A.L.S., F.R.M.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

3. 'On the Classification of the Strata between the Kimeridgian and the Aptian.' By Dr. A. P. Pavlow, Professor of Geology in the University of Moscow, For.Corr.G.S.

The following specimens, photographs, and maps were exhibited :—

Specimens and photographs exhibited by A. Strahan, Esq., M.A., F.G.S., in illustration of his two papers.

Fossils exhibited by G. W. Lamplugh, Esq., F.G.S., and the Curator of the Woodwardian Museum, Cambridge, in illustration of the paper by Prof. A. P. Pavlow, For.Corr.G.S.

Geological Survey of England and Wales, 1-inch Map, New Series, Sheet 14, Morpeth (Solid and Drift), by H. H. Howell, W. Topley, G. A. Lebour, and G. Barrow; also Sheet 343, Weymouth, by C. Reid and A. Strahan, presented by the Director-General of H.M. Geological Survey.

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April 15th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

Henry Slade Childe, Esq., Assoc.M.Inst.C.E., Home Garth, Wakefield; Stanley William Ford, Esq., 180 Cromwell Road, S.W.; James Douglas Hay, Esq., 17 Adamson Road, Belsize Park, N.W.; Osbert Henry Howarth, Esq., C.E., 259 Gresham House, Old Broad Street, E.C.; and Hastings Montague Page, Esq., College of Science,

Poona, Bombay, were elected Fellows; Prof. Albert Heim, of Zürich, was elected a Foreign Member; and Prof. S. L. Penfield, of New Haven (Conn.), and Dr. J. Walther, of Jena, were elected Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced that a portrait in sepia of Prof. Bonney, executed by Mr. Trevor Haddon, had been presented to the Society by 34 subscribers, Fellows of the Society.

The following communications were read:—

1. 'The Junction-Beds of the Upper Lias and Inferior Oolite in Northamptonshire.—Part I. Physical and Chemical.' By Beeby Thompson, Esq., F.G.S., F.C.S.<sup>1</sup>

2. 'Contributions to the Stratigraphy and Palæontology of the *Globigerina*-limestones of the Maltese Islands.' By J. H. Cooke, Esq., F.L.S., F.G.S.

3. 'On the Geology of the Neighbourhood of Carmarthen.' By Miss Margaret C. Crosfield and Miss Ethel G. Skeat. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec.G.S.)

The following specimens, etc., were exhibited:—

Specimens and photographs, exhibited by Beeby Thompson, Esq., F.G.S., in illustration of his paper.

Specimens of Trilobites, Graptolites, etc., from the Rocks of the Carmarthen District, exhibited by J. E. Marr, Esq., F.R.S., Sec.G.S., on behalf of Miss Margaret C. Crosfield and Miss Ethel G. Skeat, in illustration of their paper.

Specimen of the Phosphatic Bed at the base of the Inferior Oolite Series, Tianavaig, Skye, collected by H. B. Woodward, Esq., F.G.S., and exhibited by the Director-General of H.M. Geological Survey.

Sheet 11 of the Geological Survey of England and Wales, scale 4 miles to 1 inch, presented by the Director-General of H.M. Geological Survey.

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April 29th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

E. Hubert Cunningham-Craig, Esq., B.A., Clare College, Cambridge; William Foggin, Esq., 12 Devonshire Place, Jesmond, Newcastle-on-Tyne; and Henry Ernest Hurst, Esq., Kalcoorlie, South Norwood Hill, S.E., were elected Fellows of the Society.

<sup>1</sup> Withdrawn by permission of the Council.

The List of Donations to the Library was read.

The following communications were read :—

1. 'Descriptions of New Fossils from the Carboniferous Limestone.—I. On *Pemmatites constipatus*, sp. nov., a Lithistid Sponge. II. On *Palæacis humilis*, sp. nov., a new Perforate Coral; with Remarks on the Genus. III. On the Jaw-apparatus of an Annelid, *Eunicites Reidia*, sp. nov.' By George Jennings Hinde, Ph.D., F.R.S., F.G.S.

2. 'The Eocene Deposits of Dorset.' By Clement Reid, Esq., F.L.S., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

3. 'Discovery of Mammalian Remains in the Old River-gravels of the Derwent near Derby.'—Part I. By H. H. Arnold-Bemrose, Esq., M.A., F.G.S. Part II. By R. M. Deeley, Esq., F.G.S.

The following specimens were exhibited :—

Specimens and microscope-sections of Fossils from the Carboniferous Limestone, exhibited by Dr. G. J. Hinde, F.R.S., F.G.S., in illustration of his paper.

A series of Pebbles from the Reading and Bagshot Beds of Dorset, exhibited by Clement Reid, Esq., F.L.S., F.G.S., in illustration of his paper.

Mammalian Remains (*Hippopotamus*, *Elephas*, and *Rhinoceros*) from the old River-gravel at Allenton, near Derby, exhibited by H. H. Arnold-Bemrose, Esq., M.A., F.G.S., and R. M. Deeley, Esq., F.G.S., in illustration of their paper.

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May 13th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

J. McClelland Henderson, Ph.D., Box 1146, Johannesburg, S.A.R.; James Gunson Lawn, Esq., 7 Amerland Road, Wandsworth, S.W.; and Thomas Wilkins, Esq., 19 Lyndhurst Road, S.E., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'An Account of a Head or Gateway driven into the Eastern Boundary-fault of the South Staffordshire Coal Field.' By William Farnworth, Esq., F.G.S.

2. 'On the Geographical Evolution of Jamaica.' By J. W. Spencer, M.A., Ph.D., F.G.S.<sup>1</sup>

3. 'Dundry Hill: its Upper Portion, or the Beds marked as Inferior Oolite (G 5) in the Maps of the Geological Survey.' By S. S. Buckman, Esq., F.G.S., and E. Wilson, Esq., F.G.S.

The following specimens and photographs were exhibited:—

Specimens of Rocks and Fossils (Ammonites, etc.), exhibited by S. S. Buckman, Esq., F.G.S., and E. Wilson, Esq., F.G.S., in illustration of their paper.

Photographs of the Old Quarries at Tilly Whim, and of Durlleston Head, Swanage, exhibited by Horace W. Monckton, Esq., F.L.S., F.G.S.

Coal-Measure Sandstone from Gornal near Dudley, exhibited by W. Farnworth, Esq., F.G.S., on behalf of the Rev. W. A. H. Lewis.

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May 20th, 1896.

*Special General Meeting—8 p.m.*

Dr. HENRY HICKS, F.R.S., President, in the Chair.

On behalf of the Council the PRESIDENT submitted the following resolution to the Meeting:—

'That it is desirable that the collections of specimens belonging to the Geological Society, with the exceptions specified in the Reports of the Special Museum Committee adopted by the Council on November 20th and December 4th, 1895, be transferred to the British Museum, subject to the conditions provisionally accepted by Sir William Flower on behalf of the Trustees of the British Museum.'

The following amendment was then moved by Mr. HUDLESTON and seconded by Col. GODWIN-AUSTEN:

'That such portions of the Society's collections as illustrate papers in the Society's publications, or have a special interest in connexion with the history of geology in this country, be retained, but that all other portions may be disposed of.'

This amendment was afterwards withdrawn, and the previous question, moved by Mr. HUDLESTON and seconded by Mr. CARRUTHERS, was voted by 35 Ayes to 12 Noes.

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<sup>1</sup> Withdrawn by permission of the Council.

May 27th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

Martin Stanger Higgs, Esq., Clarence House, Gloucester; Thomas James Moss-Flower, Esq., Carlton Chambers, Baldwin Street, Bristol; and Edwin Percy Richards, Esq., 17 Market Street, Edenfield, Bury, were elected Fellows of the Society.

The List of Donations to the Library was read.

The PRESIDENT announced that a portrait in oils of the late Prof. Huxley had been presented to the Society by Sir John Evans, K.C.B., For.Sec.G.S.

The following communications were read :—

1. 'On the Pliocene Deposits of Holland, and their Relation to the English and Belgian Crags; with a Suggestion for the Establishment of a new Zone "Amstelian" and some Remarks on the Geographical Conditions of the Pliocene Epoch in Northern Europe.' By F. W. Harmer, Esq., F.G.S.

2. 'The *Lingula*-Flags and Igneous Rocks of the Neighbourhood of Dolgelly.' By Philip Lake, Esq., M.A., F.G.S., and S. H. Reynolds, Esq., M.A., F.G.S.

3. 'The Kildare Inlier.' By S. H. Reynolds, Esq., M.A., F.G.S., and C. I. Gardiner, Esq., M.A., F.G.S.

The following specimens were exhibited :—

Fossils, rock-specimens, and microscope-sections, exhibited by Philip Lake, Esq., M.A., F.G.S., and S. H. Reynolds, Esq., M.A., F.G.S., in illustration of their paper.

Rock-specimens, microscope-sections, and photographs, exhibited by S. H. Reynolds, Esq., M.A., F.G.S., and C. I. Gardiner, Esq., M.A., F.G.S., in illustration of their paper.

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June 10th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

Walter Taylor, Esq., 6 Upper Chorlton Road, Brooks Bar, Manchester, was elected a Fellow of the Society.

The names of certain Fellows were read out for the first time, in conformity with the Bye-Laws, Section VI. Article 5, in consequence of the non-payment of Arrears of Contributions.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherland.' By J. Horne, Esq., F.R.S.E., F.G.S., and E. Greenly, Esq., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

2. 'The Geology of the Eastern Corner of Anglesey.' By E. Greenly, Esq., F.G.S.

3. 'Seismic Phenomena in the British Empire.' By M. F. de Montessus de Ballore, Captain of Fortress Artillery at Belle-Ile-en-Mer. (Translated by L. L. Belinfante, B.Sc., B. ès L. Communicated by Sir Archibald Geikie, D.Sc., F.R.S.)

The following specimens, etc., were exhibited :—

Rock-specimens from Eastern Sutherland, with microscope-sections, exhibited by J. Horne, Esq., F.R.S.E., F.G.S., and E. Greenly, Esq., F.G.S., in illustration of their paper.

Microscope-sections and rock-specimens from East Anglesey, with photographs and 6-inch map, exhibited by E. Greenly, Esq., F.G.S., in illustration of his paper.

Tooth of *Cestracion rugosus* from the Upper Chalk, Strood, Rochester, exhibited by G. E. Dibley, Esq., F.G.S.

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June 24th, 1896.

Dr. HENRY HICKS, F.R.S., President, in the Chair.

The PRESIDENT said: It is with deep regret that I have to announce to you the death of our dear and much-beloved friend, Sir Joseph Prestwich. He was elected into the Society in the year 1833, and we had come to look upon him as the father of our Society. He served it as Treasurer and President, and was one of its Wollaston Medallists, and we feel that by his death our Society loses one of its truest friends. He always gave us of his best, and delighted to communicate his knowledge to his fellow-workers. He was in every respect a typical representative of our Society and its objects, for he passionately loved the science, fearlessly maintained what he believed to be the truth, and had that open mind and craving for knowledge which have ever characterized the best and

noblest of its members. This is not the time to refer specially to his labours; but we may feel assured that such sterling work as he accomplished will ever hold an honoured place in the annals of British Geology. The Council at their sitting this afternoon passed the following resolutions, which I feel no doubt all the Fellows present will cordially endorse:—

(1) That the President, Council, and Fellows of the Geological Society of London desire to convey to Lady Prestwich the assurance of their heartfelt sympathy with her in the sad and irreparable loss that she has sustained, and at the same time to place on record their high appreciation of the lifelong geological work achieved by Sir Joseph Prestwich, who for sixty-three years was a member of their body alike respected and beloved.

(2) That this Resolution be placed upon the Minutes, and that a copy of it be communicated to Lady Prestwich.

The above Resolutions were then passed unanimously.

Humphrey Lewis, Esq., Cambrian House, Llangollen; Geoffrey F. Monckton, Esq., Vancouver, British Columbia; and William Sherwood, Esq., Eastbourne House, Sutton Coldfield, were elected Fellows of the Society.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-laws, Section VI. Article 5, in consequence of the non-payment of their Arrears of Contributions:—the Rev. J. T. C. GULLAN; F. McKNIGHT, Esq.; E. P. RAMSAY, Esq.; and R. H. WILLIAMS, Esq.

The List of Donations to the Library was read.

Sir WILLIAM DAWSON, C.M.G., F.R.S., exhibited specimens and lantern-slides illustrating the general form, arrangement of laminæ, and distribution of the canals and tubuli in characteristic specimens of *Eozoon canadense*. He pointed out that an examination of these specimens and photographs might prevent mistakes likely to arise from the study of imperfect specimens or from supposing that laminated rocks resembled *Eozoon*, and also that they exhibited additional peculiarities observed since the original publication of the description of *Eozoon* in the Quarterly Journal of the Society in 1865. He did not wish to enter upon any argument as to the nature of *Eozoon*, but merely to show the appearance of the principal structures on which the conclusion that it was of animal origin had been based. He also pointed out that these structures might be misunderstood when studied in imperfectly-preserved specimens, and

that the wonder was not that so many specimens were imperfect, but that any structure had been preserved. He also shortly noticed the growing probabilities in favour of the existence of a rich marine fauna in pre-Cambrian times, and some of the discoveries in this direction already made or in progress.

The following communications were read:—

1. 'Notes on the Glacial Geology of Arctic Europe and its Islands.—Part II. Arctic Norway, Russian Lapland, Novaya Zemlya, and Spitsbergen.' By Col. H. W. Feilden, F.G.S. With an Appendix by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

2. 'Extrusive and Intrusive Igneous Rocks as Products of Magmatic Differentiation.' By Prof. J. P. Iddings, For.Corr.G.S.

The following specimens, etc., were exhibited:—

Rock-specimens and fossils, exhibited by Col. H. W. Feilden, F.G.S., in illustration of his paper.

Lantern-slides and microscopic sections of *Eozoon canadense*, exhibited by Sir J. William Dawson, C.M.G., F.R.S., F.G.S.

Sheet 7 (N.W. Wales) of the Geological Survey Index Map, on the scale of 4 miles to 1 inch, presented by the Director-General of that Survey.



# ADMISSION AND PRIVILEGES

OF

## FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

EVERY Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribution paid by Fellows is Two Guineas, due on the 1st of January in every year, and payable in advance; but Fellows elected after the month of February are subject only to a proportionate part of the Contribution for the year in which they are elected, and Fellows elected in November or December pay no Contribution for the current year. The Annual Contribution may at any time be compounded for by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes of the Quarterly Journal of the Society that may be published after their election, so long as their Annual Contributions are paid; and they may purchase any of the publications of the Society at a reduction of 25 per cent. under the selling prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (except during the first two weeks of September), and on Meeting days until 8 P.M.; see also next page. Under certain restrictions Fellows are allowed to borrow books from the Library.

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[No. 209 will be published on the 1st of next February.]

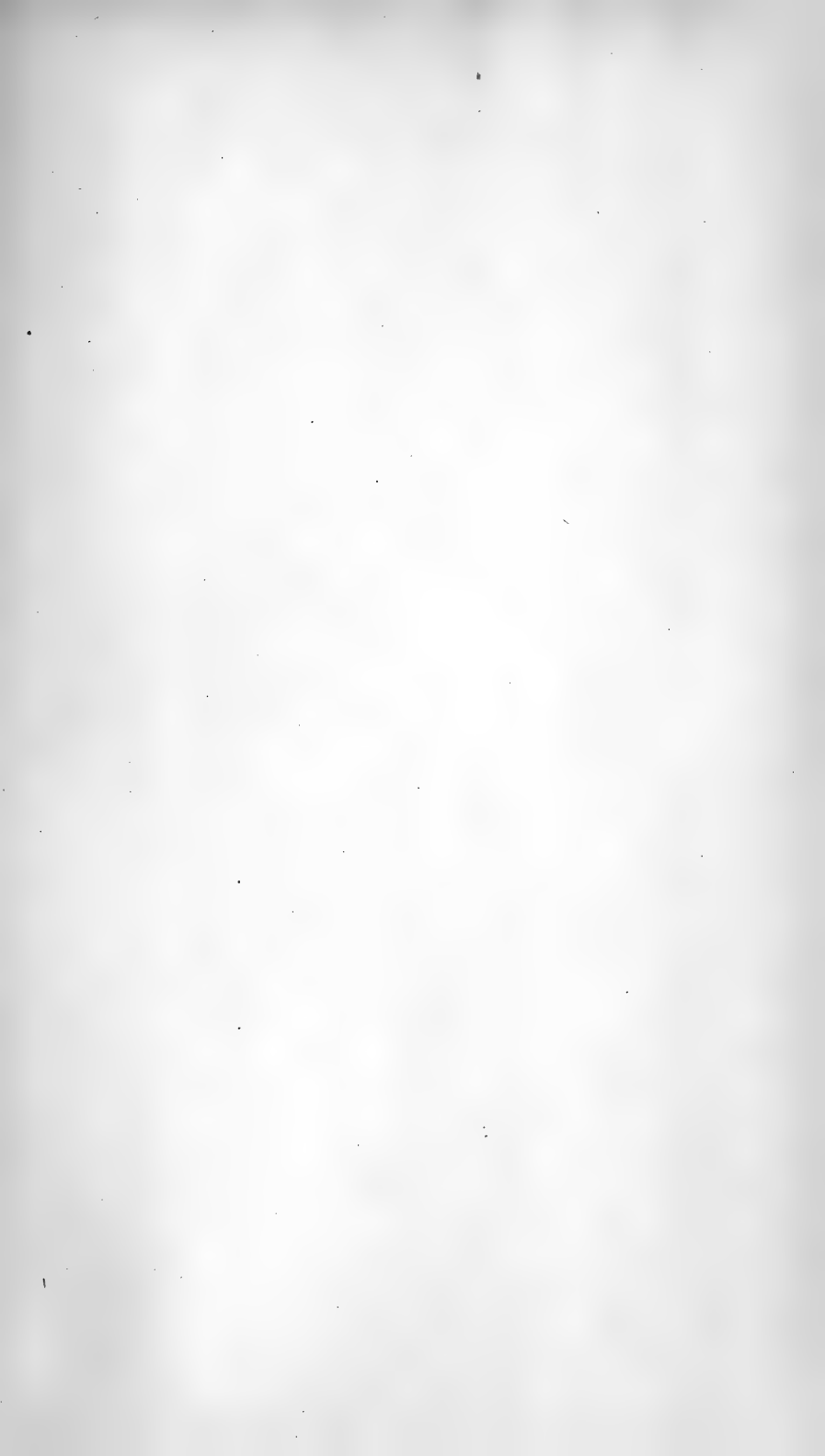
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\*\* The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, except during the first two weeks in the month of September, when the Library will be closed for the purpose of cleaning; the Library is also closed on Saturdays at One p.m. during the months of August and September. It is open until Eight p.m. on the Days of Meeting for the loan of books, and from Eight p.m. until the close of each Meeting for conversational purposes only.

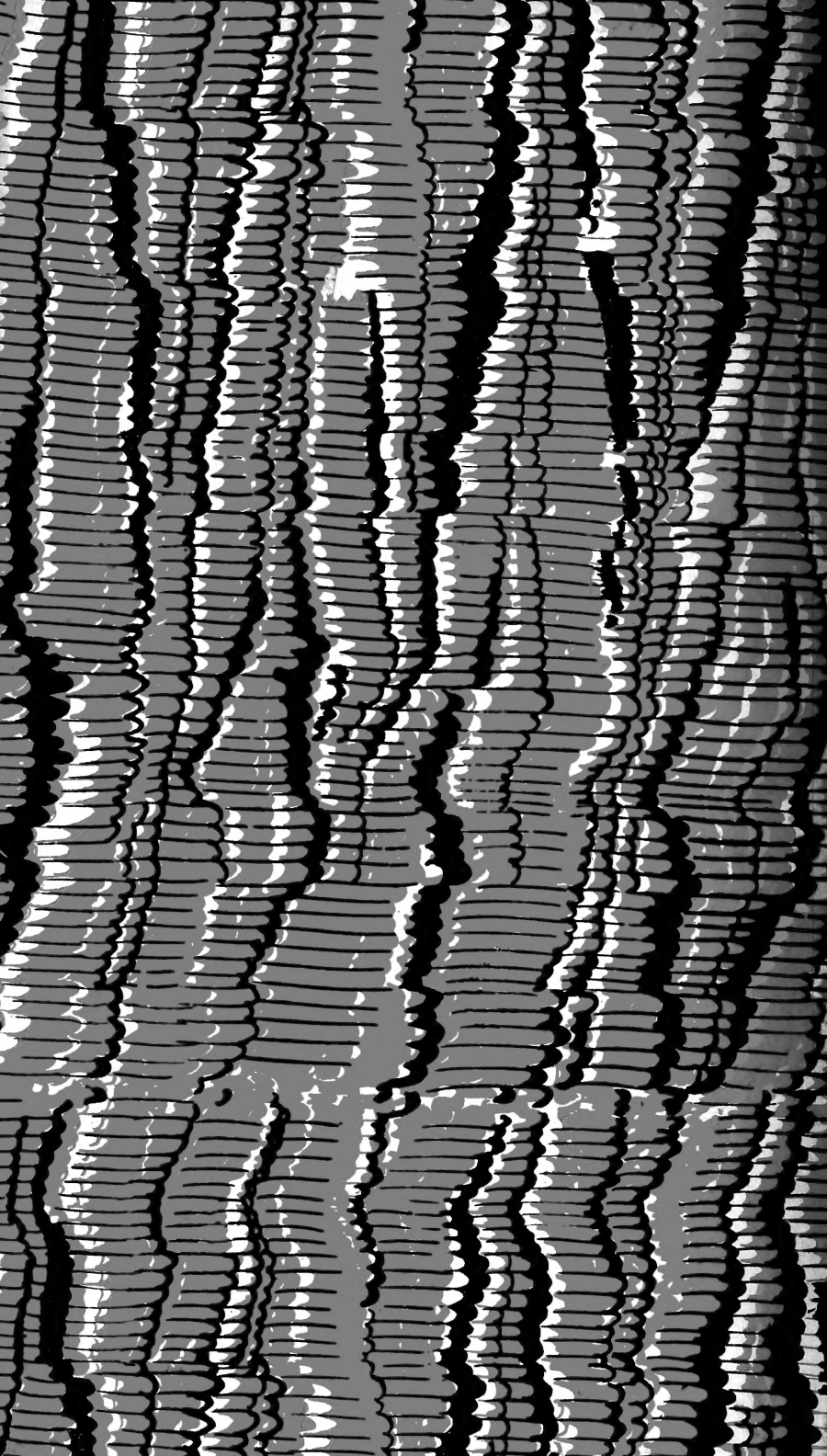




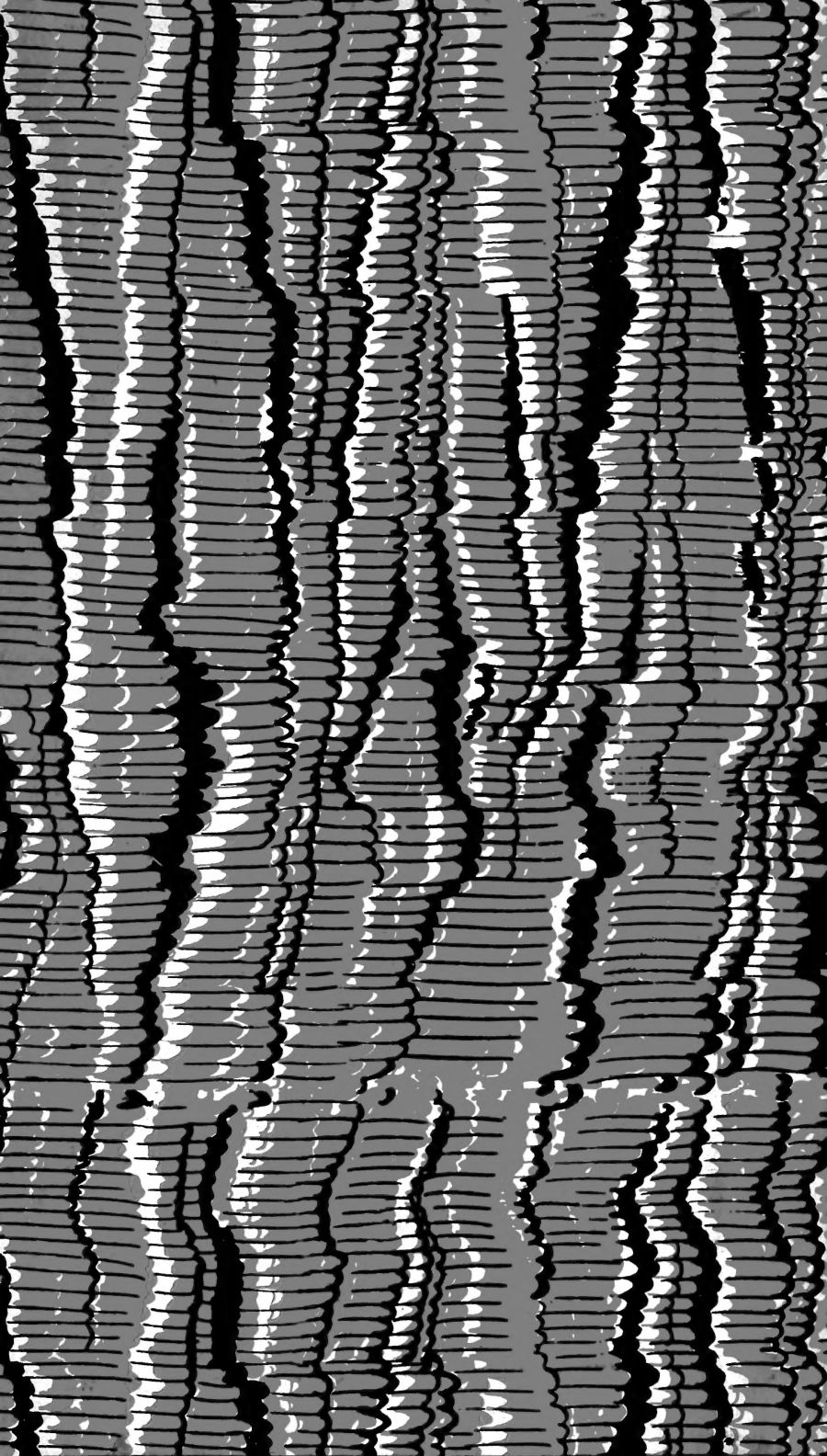












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